Chapter 6

Media

"Media" refers to the abrasive or non-abrasive consumable elements (chunks) used in mass finishing processes[1]. The main function of media is to abrade or burnish the edges and surfaces of components to the desired finish. Media also helps keep workpieces from impinging on each other and serves as a carrier for any compounds used. Steel media also can compact surfaces and transfer their lustrous finish to the parts.

6.1 SELECTION OF MEDIA

Selection of the proper media for a specific application is critical for optimum deburring and surface finishing results. Unfortunately, the choice of media is difficult for those with no experience because of the diversified requirements of numerous applications and workpieces and the wide variety of types, sizes, and shapes of media available. In many cases, optimum selection must be made on a trial-and-error basis. This and following chapters provide detailed guides for media selection and use that are of particular benefit to the people new to the processes.

Major selection factors to consider are composition (type), size, shape (Fig. 6-1), and weight of the media to be used. Other important considerations include the capability, economy, and versatility of the media. Workpiece material, size, and geometry, burr sizes and locations, finishing requirements, finishing equipment used, and subsequent operations and functions of the workpieces are also critical factors. Some general considerations with respect to media selection are presented in Tables 6-1, 6-2, and 6-3. Magnetic separation of ferrous parts generally requires the addition of demagnetizing equipment. This is very important if parts are to be plated.

6.1.1 Media Composition

The composition of a media determines whether it is a cutting or finishing type of media. Figure 6-2 illustrates conceptually the effect of composition on surface roughness (Kittredge 1981a). Cutting types of media contain abrasives while finishing types have no abrasives or only very fine abrasives. Workpiece material, its hardness, size of burrs, and surface finish requirements all govern the type of media to be used.

As one author notes, media is similar to a grinding wheel (Kittredge 1981a). As the grinding wheel cuts, abrasive grain is lost, the wheel gets smaller, and, as a result, fresh media is exposed. The media wears as it rubs against parts and against other media constantly exposing fresh grains. Ceramic media is typically made with up to a 50:50 ratio of abrasive to clay. Higher abrasive content provides faster cutting. Hard ceramic media (hard clay) typically cuts slower than soft ceramic, which allows the clay to wear away exposing more grains of abrasive.

[1]Although "media" is the plural of "medium," it is used as a singular in mass finishing literature; we hold to this usage here.

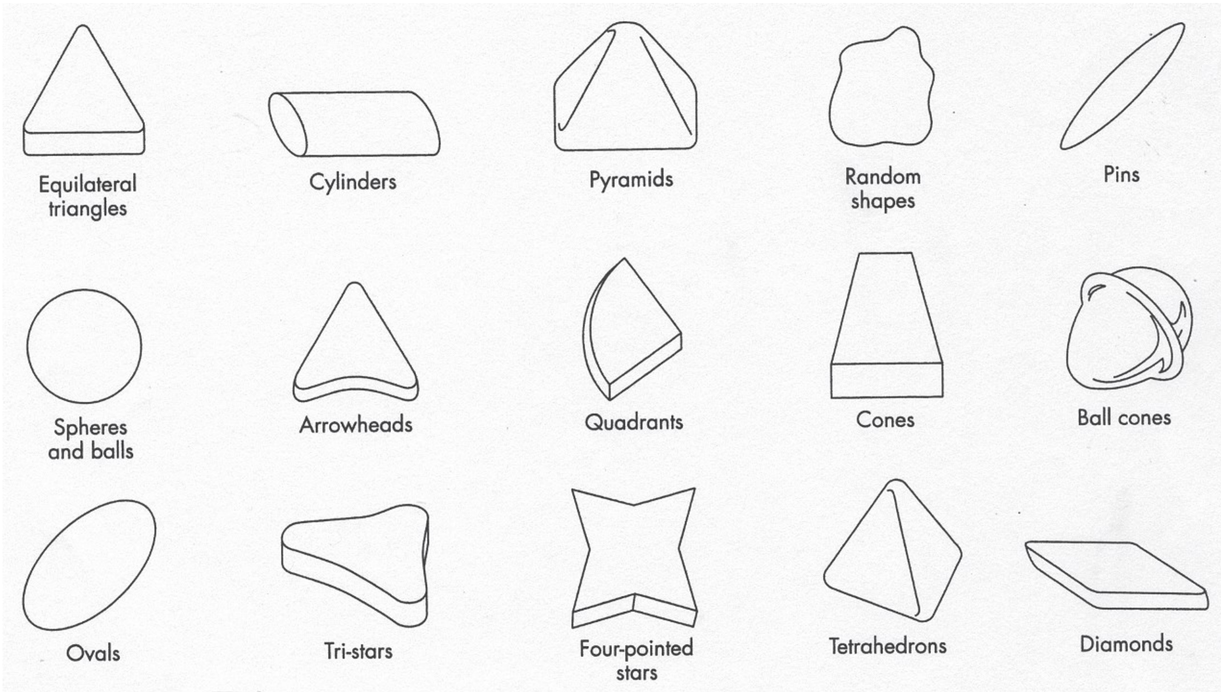

Figure 6-1. Media shapes used for mass finishing

Oven temperatures and curing time determine ceramic hardness. High amounts of abrasive in the media and cooler firing temperatures result in high ceramic wear and fast cutting rates.

Media with aggressive cutting capabilities is generally best for the removal of large burrs. Requirements for smooth surface finishes necessitate the use of slower cutting media with fine or no abrasives. Harder media can generally be used in the high-energy methods of mass finishing.

Media designed for rotary barrels will wear much too fast in vibratory machines Media designed for vibratory equipment will wear too fast for centrifugal barrel machines.

The composition of a media also determines its weight, which affects the rate at which work is performed. Heavier media exerts more pressure on the workpieces than lighter media does.

6.1.2 Media Shape

Different shapes of media (see Fig. 6.1) have advantages for specific applications, depending primarily upon the configurations of the workpieces. Major considerations in selecting a shape are that it:

1) provide access to all workpiece surfaces requiring deburring or finishing;
2) not lodge in holes or recesses; and
3) permit easy separation from the parts at the end of the cycle. A mixture of media shapes is sometimes used.

6.1.2.1 TRIANGLES

Media of triangular shape provides uniform action and is effective in reaching corners and slotted areas (Fig. 6-3). Angle-cut triangles have sharper corners and edges and provide deeper penetration into remote areas. Notched triangle (arrowhead) media, in addition, provides sharper edges for reaching into slots, holes, or openings. The smallest standard triangle available has a corner radius of about 0.040 in. (1.02 mm), but it is frequently desirable to use larger triangles that have larger radii since they minimize cycle time. The flat sides of triangles make them good choices for straight edges.

Table 6-1. Shapes and sizes available for media

Shape	Media Material											
	Plastics Size (in.)	Ceramic Al2O3 size (in.)	Silicon carbide size (in.)	Hard metal size (in.)	Soft metal size (in.)	Wood size (in.)	Zine size (in.)	Flint	Novaculite	Garnet	Pumice	Limestone
Cylinders		3/16 to 1-1/8										
Elliptical cylinders		5/16 to 7/8										
Cones	1/4 to 2-1/2	3/8 to 1-1/8										
Triangles	1/4 to 2-1/4	3/16 to 2	1/4									
Tri-stars	5/8 to 2	3/8 to 1-1/2										
Arrowheads	1-3/4	5/8										
Quadrants												
Pyramids	1/4 to 2	7/8 to 2										
Wedges	3/4 to 2-1/2	3/8 to 1-1/2										
Four-pointed stars		1-1/2										
Tetrahedrons	1/4 to 1-3/8	1-1/8 to 2.0										
Polyhedrons	3/8 to 5/8	3/8										
Diamonds		1-5/8 to 1-1/2				X						
Spheres	3/32 to 3/4	11/64 to 13/16			X	X						
Random shapes		Size 240 to 00	Size 240 to 00	0.006 to 7/8	0.006 to 7/8			Size 240 to 00	Size 240 to 00	Size 240 to 00	Size 240 to 00	Size 240 to 00
Spheres with flats on ends												
Pins				3/64 to 1/8	3/64 to 1/8				X	X		
Ball cones				1/8 to 3/8	1/8 to 3/8							
Oval cones				0.245 to 0.630	0.245 to 0.630							
Metal cones												
Serrated cylinders				7/32 to 1/8	7/32 to 1/8							
Diagonal cylinders				3/32 to 3/8	3/32 to 3/8				X	X		
Pegs						3 to 6						
Blocks						5/16 to 4						
Cylindrical wedges	1/2 to 2-1/2											
Trimids	1-1/2 to 2											
Trapezoids						X						

Table 6-2. Properties of various media

Media	Materials	Sizes	Aggressiveness	Shapes
Random natural	Limestone, river rock, granite, Turkish emery, American emery, novaculite, garnet	#00-24 size (2.0 to 0.028 inch) [19 standard sizes]		random
Random synthetic	Fused aluminum oxide (3 variations), crushed plastic, silicon carbide	#00-24 size (2.0 to 0.028 inch) [19 standard sizes]		random
Preformed ceramic	Porcelain filled with aluminum oxide grit or silicon carbide grit		Extra fast cut, fast cut, medium cut, moderate cut, slow cut	20 shapes; see Figure 6-1
Preformed plastic	No common material grades between suppliers		At least 9 grades	18 shapes
Preformed steel & metal	Stainless steel, chrome alloy hardened, high carbon steel, low carbon steel, Monel, tool steel, tungsten carbide, brass	27 ball sizes, 8 diagonal sizes, 6 pin sizes		6 shapes
Preformed wood		14 total wood shape sizes		6 shapes
Ground corncob				

Table 6-3. Media selection guide for mass finishing (Kittredge 1993)

Desired Effect	Degree of Effect	Media Recommended
Deburring	Light	Steel or ceramic
	Medium to heavy	Ceramic or plastic
Radiusing	Light to heavy	Ceramic or plastic
	Irregular surfaces	Randomly shaped
Surface roughness	Reduce to lower value.	Plastic or ceramic
	Pre-plate quality on softer alloys	Plastic or ceramic
		Plastic → plastic
		Plastic 2 → steel
		Ceramic 2 → steel
		Steel or wood
Surface reflectivity	Brighten or highlight	Steel or ceramic
	Best quality, hard alloys	Ceramic or ceramic 2 → steel
	Best quality, soft alloys	Plastic 2 → steel
	Best quality, plastics	Wood
Clean surfaces	All metals	Steel or ceramic
Least operating cost	Varies greatly with grade involved	Steel, ceramic, plastic or wood
		Steel, ceramic, plastic, or wood
Fastest processing speed	Overall capabilities of media must be understood	Steel, ceramic, plastic, or wood

Note: Some media may be inappropriate for overall part requirements. Two-step processes are denoted by “ 2 →” between media steps. Media not listed does not imply unsuitability.

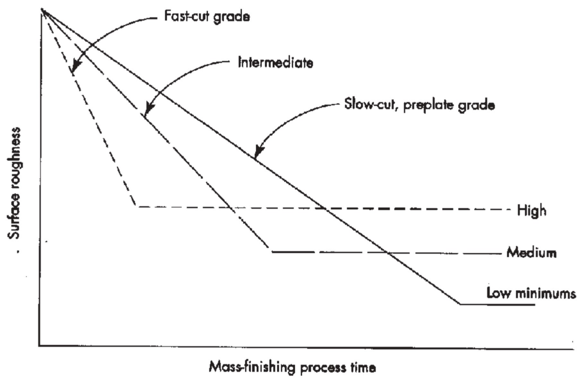

Figure 6-2. Relationship of media types to surface finish produced (Kittredge 1981a)

6.1.2.2 CYLINDERS

Cylindrical shaped media works effectively in some applications. With its ends cut at angles of 22 to 60°, cylindrical media reaches recesses more easily. Cylinders and cones are ideal for deburring holes and contours (Fig. 6-3).

6.1.2.3 DIAMONDS

Diamond-shaped media has sharp points that can reach into corners, slots and recesses without lodging problems.

6.1.2.5 CONES

Conical-shaped media is very versatile. It permits partially entering holes of various diameters without lodging problems (Fig. 6-3).

6.1.2.5 SPHERES

Spherical-shaped media has good flow action and surface contact. It is useful for uniformly blending and smoothening of surfaces.

6.1.2.6 WEDGES

Cylinders that are cut into wedge shapes have become one of the most popular shapes replacing cones, plain cylinders, and triangles in many applications. Manufacturers use several names for these shapes including double cut cylinder, "V"-cut cylinders and tri-cylinders.

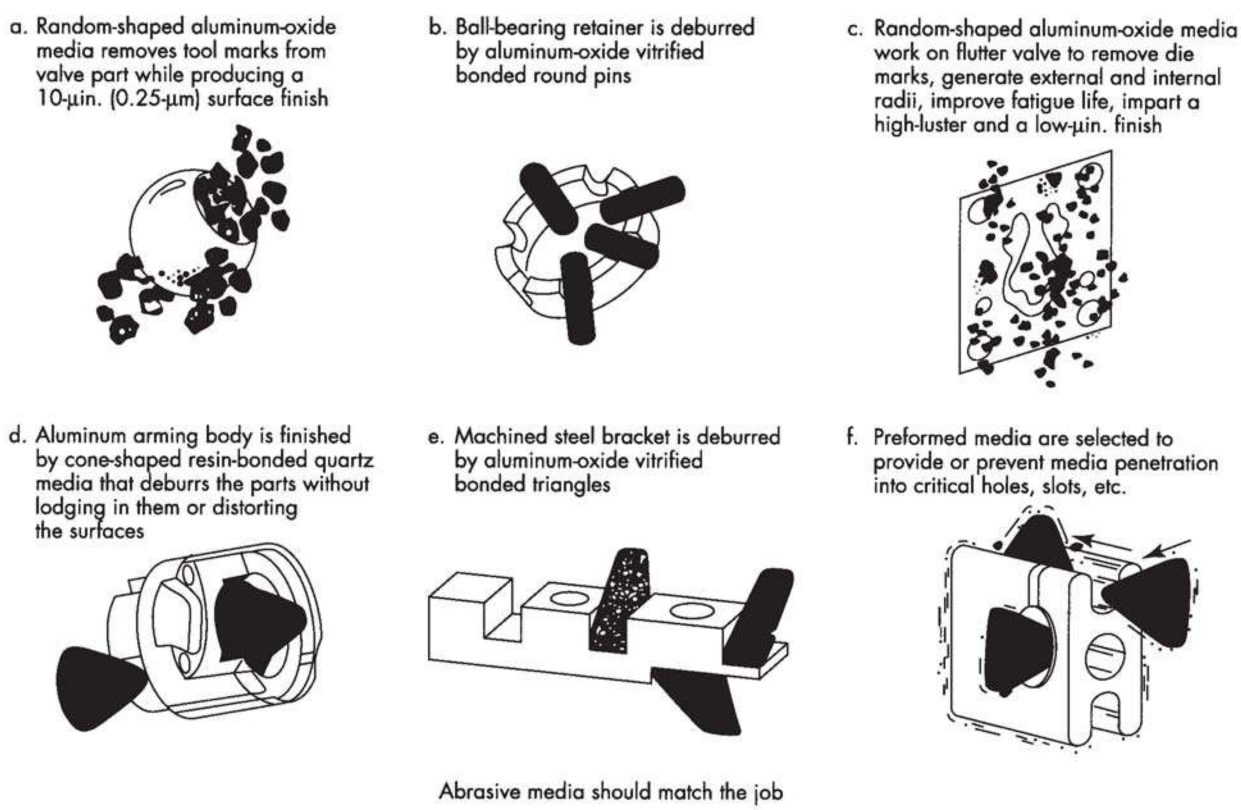

Figure 6-3. Examples of media matched to part features (McCandless 1967)

6.1.3 Media Size

The size of the media used is important for several reasons. One function of size is to help keep the workpieces separated during finishing. Small-sized media helps keep small parts separated. On the other hand, large media cuts faster and produces a rougher finish than small media. As a result, a mixture of media sizes is often used for processing parts.

Another important consideration is that the size of the media must allow for reaching all surfaces to be finished without lodging in holes and recesses of the workpieces. The ease with which the media can be separated from the workpieces must also be analyzed. With separation by screening, the media must be either larger or smaller than the workpieces. However, with magnetic separation of ferrous parts, media size in relation to workpiece size is not a factor. Smaller media can generally be used in the high energy methods of mass finishing without increasing cycle times significantly, yet it improves the surface finishes produced. Chapter 5 discusses the relationship between media size and part features. Tables 4-6 and 4-7 present dimensions of random-shaped media. Figures 6-4 and 6-5 illustrate the impact that media size has on edge finishing in centrifugal barrel machines. Similar relationships exist for most mass finishing operations.

Because media wears with use, it must be occasionally screened (often referred to as "classification") to remove undersize media that otherwise will lodge in small features.

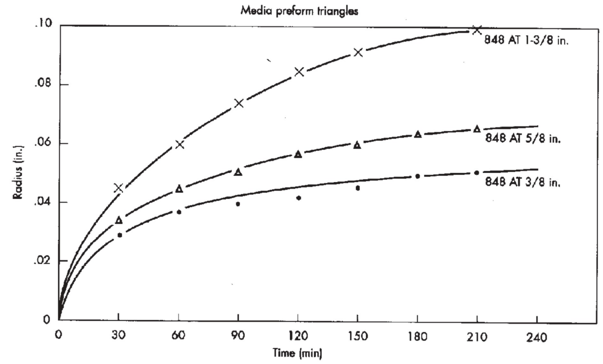

Figure 6-4. Effect of media size on edge radius in centrifugal barrel at a gravity force of 25. Data are based on using 1.5 × 1.5 in. (38 × 88 mm) cube or cylinder parts run at a gravity force of 25 in normal operation. Numbers containing the letter R are random-shaped aluminum oxide, and the number after the R represents the grit size (that is, 651R 1-1/2 represents random-sized chunks averaging 1.5 in. (38 mm) Media numbers containing the letter T are plastic-bonded triangles, and those with the letters AT are ceramic-bonded triangles (Hignett 1976)

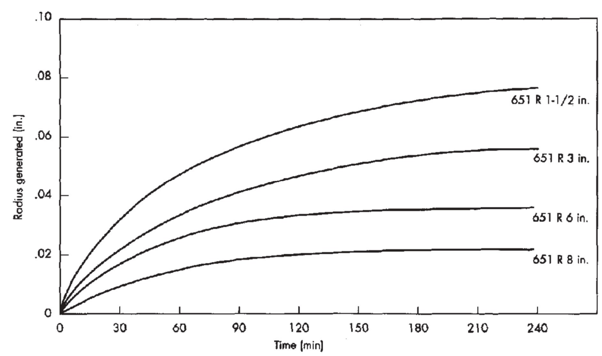

Figure 6-5. Effect of random media size on edge radius in centrifugal barrel at a gravity force of 25. Data are based on using 1.5 × 1.5 in. (38 × 38 mm) cube or cylinder parts run at a gravity force of 25 in normal operation. Numbers containing the letter R are random-shaped aluminum oxide, and the number after the R represents the grit size (that is, 851R 1-1/2 represents random-sized chunks averaging 1.5 in. [38 mm]). Media number containing the letter T are plastic-bonded triangles, and those with the letters AT are ceramic-bonded triangles (Hignett 1976)

6.1.4 Media Weight

As noted above for a given set of operating conditions a heavy media exerts more pressure on the part than a light media does. This weight allows faster cutting, but it also causes thin or ductile parts to bend or distort. Smoother heavy media provides a better polishing than lightweight media does. Table 6-4 provides a comparison of common media and their weights.

6.1.5 Media Capability

A most important consideration in media selection is the ability of the media to remove burrs and produce the required corner edge and surface conditions with consistent uniformity. Cycle times required to achieve these results are also critical. Minimum break-in requirements, wear, and reclassification needs, as well as good cushioning action, are desirable features. The internal

Table 6-4. Mass finishing media weights

Media	Weight, lb/gal (kg/L)	Weight, lb/ft^3 (kg/m^3)
Walnut shells	5.5 (0.7)	39 (624)
5/16-in. ceramic cylinders	12.8 (1.5)	90 (1442)*
Carpet tacks	20.0 (2.4)	150 (2403)
0.5-in. steel balls	38.5 (4.6)	287 (54 balls/lb) (4599)
120 grit aluminum oxide	15.7 (1.9)	118 (1891)
Plastic media	7.3 (0.9)	55 (881)
Corncobs	3.9 (0.5)	28 (449)
Silicon carbide (SiC)	10.6 (1.2)	75 (1202)
Ceramic bonded preforms	12.0 (1.4)	85 (1362)

*Ceramic media can vary from 85–125 lb/ft^3 (1362–2002 kg/m^3).

composition of the media is the source of cutting action, weight, wear, and surface finishes.

6.1.6 Versatility

Other features desirable in media include the ability to finish a variety of workpieces in a given machine and the ability to achieve different finishes.

6.1.7 Economy

Cost per pound of different media is of little significance in overall economic considerations. Wear characteristics of the media and cycle times to attain the required results must be considered when a manufacturer determines the all-important *cost per finished part*. The impact of media wear on costs is discussed in a later part of this chapter.

6.1.8 Availability

The consistent availability of uniform, high-quality media from a reliable supplier is another important consideration. If the manufacturer or supplier of media requires media with different cutting or polishing action on each order, the user will experience many time consuming problems. Consistency of media is important for consistency of results. Shuffling between media when media is not available will not produce acceptable results. Having the preferred media when needed is essential to cost effective finishing.

6.2 TYPES OF MEDIA MATERIAL (COMPOSITION)

The most important types of mass finishing media, from the standpoint of most common usage, include natural abrasives, agricultural products, synthetic random media, preformed ceramic and resin-bonded media, and metallic media.

6.2.1 Natural Abrasives

Quarried, crushed, and graded stones were the original mass finishing media. They have, however, been largely replaced by synthetic materials primarily because natural stones are softer, wear more rapidly, are less consistent, and occur only in random shapes. Synthetic materials are harder, provide longer life, and have more consistent cutting action, wear rate, and dimensions.

The random natural media include natural stones of several popular types including granite, limestone, river rock, Turkish emery, American emery, and others. These are low cost media, but in general are not cost effective for the majority of parts deburred. Granite is very hard and is often used as a carrier for the compound. Despite their limitations, natural abrasives still have some applications. Corundum is a natural crystalline oxide of aluminum (Al_2O_3) that can be economical for some uses. It is often distinguished by its red, dark brown, or black color. Novaculite is a fine-grained silica stone (siliceous rock) that maintains sharp particle shapes and can be of value for removing burrs from small holes and grooves.

Soft limestone and hard but more friable granite can still be economically justified for some barrel finishing applications. Limestone is sometimes used for gentle cut-down of nonferrous metals, especially zinc, aluminum, and copper. Natural abrasives are sometimes used in the manufacture of bonded preforms. Unfused alumina is often used with hard wood shapes or nylon slugs for deburring plastics.

6.2.2 Agricultural and Wood Products

Ground corncobs and walnut or other nutshells, as well as hardwood sawdust, are used in tumbling barrels and heated barrels for drying parts. These materials produce a good luster on some workpieces. When mixed with fine abrasives they are suitable for fine polishing operations, particularly in the jewelry industry. The finishing media described here are typically run dry and the process is referred to as “dry-processing.” The fact that these materials improve surface reflectivity, or luster, in a mass operation makes them particularly attractive in the finishing of many products (Davidson 1989).

Wood shapes, such as cubes, the conventional peg, dual wedge-ended pegs, diamonds pegs, or wedge-ended pegs, are made from hard woods (especially maple, oak, and beech). They are used to deburr and finish wood, plastic, ceramic, and metallic components. Sometimes they are coated with oils or waxes to transfer coatings to the workpieces or fine abrasives for increased cutting action. Other wood shapes used for finishing include dual wedge-ended pegs and diamonds. Granules from ground corncobs, walnut shells, or even flakes are other forms taken by this media. Hardwood media can duplicate the effect of color buffing on plastics, wood, or soft metals. Granules used in centrifugal barrel finishing equipment are smaller than in other mass finishing operations. Smaller sizes are also used for polishing softer materials; the harder granular media should be avoided (Davidson 1989). Note that the hard woods typically have half the density of plastic media.

Dry media is also useful for removing firing sand from ceramic parts (Davidson 1989). This media is also used to create a variety of effects on hard wood products, as well as to coat the wood parts. In barrel operations large numbers of parts can be stained, oiled, or coated with other materials without worrying about the material handling operations of wet spray coating (Davidson 1989).

6.2.3 Synthetic Random Media

Fused aluminum oxide ($A1_20_3$), crushed and graded, has greater abrasion properties than some natural materials. Other advantages include good wear resistance and consistency of size and quality. However, the physical characteristics of fused aluminum oxide vary with different producers. Fused aluminum oxide is a by-product of refining bauxite. It is, for practical purposes, a single crystal. Sintered aluminum oxide is the longest lasting random-shaped abrasive material available for mass finishing. Sintered or bonded aluminum oxide is made by combining a uniform size of aluminum oxide with a bonding agent. It is used extensively for fine deburring and finishing. Random synthetic media (crushed plastic) is often filled with one of two distinct grades of fused aluminum oxide. One grade helps accelerate cutting and another helps brighten parts. Users have various degrees of success with this media. The same lot of media has lasted for months with daily use at one plant, while other users indicate that it wears very fast and cuts very little. Lodging of media in holes is a problem with any random-shaped media.

Fused silicon carbide (SiC) media is available, but sizes above about 1/4-inch (6-mm) diameter fracture too readily to be well suited for mass finishing. This synthetic mineral may have to be used for components that are subsequently brazed, soldered, or welded, and when aluminum oxide cannot be used. However, preformed media is normally preferred to silicon carbide for such applications.

6.2.4 Preformed Media

The development of controlled media shape, size, and abrasion and finishing characteristics has been largely responsible for making mass finishing a precision process. Today’s cutting media consists of abrasives in a ceramic binder. This combination acts like an abrasive metering device (i.e., a given amount of abrasive appears per unit of time). Preformed media is available in ceramic, resin-bonded, and metallic types, all of which are used extensively. The abrasives used in preformed ceramic and resin-bonded media are often aluminum oxide, silica, or silicon carbide. Flint and emery are also used as abrasives in media.

The initial reason for favoring preformed ceramics over random shaped products, both natural and man-made, was to eliminate lodging problems. Early preformed products wore out very rapidly, but soon this was corrected. Today, economy joins with lodging as a reason to use preforms over random shapes.

6.2.4.1 PREFORMED CERAMIC MEDIA

Ceramic-bonded media are produced by mixing porcelain, kaolin clay, river clay or other vitreous materials with varying percentages of, or with no, abrasives. The wet material is formed into desired shapes (usually by extrusion and cutting) and then fired to vitrify. Fusion bonding is used to make some media. Such media are available in a wide range of shapes and sizes. Also, when the engineer or manufacturer selects the proper grade of abrasive, the correct proportion of abrasive to binder, and the most suitable binder, this media will adapt to a great variety of' applications and workpieces. Ceramic media with about 50% aluminum oxide abrasive of 60 grit is the fastest material for deburring, edge generation, and stock removal. Preformed ceramics, one of the two workhorse mass finishing media, are available in large number of fairly standard grades. Extra fast cut, fast cut, medium cut, moderate cut, and slow-to-no cut grades are typical. Many manufacturers make more than five grades. The binder acts as a burnishing surface, and this works against rapid cutting. By using large grains, rapid cutting is provided, but that also causes rough surfaces. Cutting media generates a dull, matte surface finish.

6.2.4.2 PORCELAIN MEDIA

Porcelain with no included abrasive is long wearing, can develop extremely good surface finishes and produces very little wear. While porcelain is an ingredient in some of the cutting media, manufacturer's literature may distinguish porcelain from cutting media. Because it is non-abrasive it brightens the surface of most metals. Work hardening materials may not brighten like non-work hardening alloys, however.

6.2.4.3 PREFORMED MICROCRYSTALLINE ABRASIVE MEDIA

Consider a chunk of media made entirely of very small grains of aluminum oxide, but having no bonding agent. A thousand minute grains are compressed and sintered at a temperature that prohibits the small grains from merging together into a larger grain. This characterizes microcrystalline abrasive (Matsunaga 1971). It provides a media that cuts with a fine finish, but also has a fast cutting rate because of the "thousands" of small cutting edges. A single media with or without extra abrasive compounds provides all the needed functions for rapid cut-down and burnishing.

6.2.4.4 PREFORMED RESIN-BONDED MEDIA

Preformed plastics, the other workhorse media, are also available in a variety of grades or "bodies," with some manufacturers having nine grades while others have as few as three. Five would be a conservative compromise, if it were not for that fact that other significantly different grades are available using other binders or having higher density.

This media is formed by bonding abrasives (generally 40–70% by weight) into polyester or urea-formaldehyde resins, usually by casting. After casting, this media is typically pre-tumbled to remove flash. This "plastic media" is softer, has a lower density than preformed ceramic media, provides a cushioning effect, and sometimes has a shorter life. It is well suited for finishing softer metals and fragile parts, achieving pre-plating requirements, and producing smooth finishes as low as 2 microinches. During finishing the matrix (plastic), which is softer than the abrasive, is eroded, leaving the abrasive to perform the desired work. While some users believe it assures parts free of impingement, this is not true. All the mass finishing processes except for fixtured or compartmentalized operations allow part-on-part contact. Plastic media can also be produced in a wide variety of desirable shapes. In practice over a decade some shapes go out of favor and new ones emerge.

One manufacturer notes that the plastic media provides "...no surface hardening of the workpieces" (Anonymous 1970). In addition, that source notes that the plastic media is also quieter than abrasive chips (sintered media).

6.2.4.5 PREFORMED LOW DENSITY POLYESTER MEDIA

One advantage of the low density plastic media is that in a vibratory tub the total weight is 30–35% less than it would be if ceramic media were used. That makes it a good choice for soft metals and high finishes since less damage will typically occur. Low density plastic is not generally used for heavy deburring. It is widely used for aluminum and pre-plate finishing of aluminum and plastic parts. It leaves residue in the tub and can cause excessive foaming in drains, however.

The silica flour in this media, which is light, dries on the parts similar to the way it would if talcum powder, chalk, or dust were in the solution. When dried, no amount of washing or post cleaning works well.

A serious problem with low density plastic media is foaming. Foam builds up in drains and becomes an effluent problem. Defoaming compounds help, but they add cost to the operation. Foam compression in enclosed machines has been tried and flames have been used to cut down the problem, but neither of these latter two are good choices. Foam carries solids in suspension and that requires large effluent disposal tanks; high density plastic has greatly reduced this issue.

6.2.4.6 PREFORMED HIGH DENSITY POLYESTER MEDIA

High density polyester media is made the same way as low density media except there is a difference in composition: a polyester resin and heavier silicate filler are used in high density media. The additional weight of the media and sharper crystal facets improve the cutting performance compared with low density media. It is also claimed that smoother surface finishes can be produced than the surfaces produced with ceramic media. The silicate filler weighs 284 lb per cu ft compared to the 151 lb per cu ft silica flour used in low density media (Southern 1983). The tetragonal crystal facets provide a sharper cut than the cubic silica crystal.

One author notes, "Silicate will not work harden the surfaces and can be used on all metal and plastic surfaces." (Southern 1983). It is not clear, however, to the author of this handbook that the abrasive in the media is the cause of part work hardening. The total weight or pressure against the part is the generally recognized reason for work hardening.

6.2.4.7 PREFORMED UREA-FORMALDEHYDE MEDIA

Urea is another of the often-used plastic materials for preforms. Urea is made from urea formaldehyde resin and catalyzed with an acidic solution. The acidic component leaves the parts clean and helps lower foam in the effluent. Because of the acidic nature it is not generally used on steel parts as it can cause corrosion; it is typically used on non-ferrous metals. It weighs about 60 lb per cu ft.

Some of the above media materials are designed to be very sensitive to the compounds used with them. The urea-formaldehyde media can be used to cut with a good deburring compound and then "color" or burnish with a soapy type compound. In contrast, other media will not allow users to do both these operations effectively. For the coloring, or burnishing, users must change to a different media or a different compound.

6.2.5 Metallic Media

Metallic media comes as either hard or soft preformed shapes designed for polishing. Preformed hardened steel media, free of abrasive, is available in a variety of shapes and sizes. It is used primarily for burnishing to achieve maximum luster for decorative purposes, for light deburring applications, and for heavy duty cleaning. Advantages include uniformity of shape and size, the elimination of possible media fracturing in use, and almost no wear. The high bulk density of steel media results in rapid peening and deburring and supports the workpieces. Preformed steel media for burnishing is case-hardened, polished, and accurate in dimensions. A few through-hardened shapes are available, as well.

Soft steel shapes are used as carriers for fine abrasive particles for deburring as opposed to the hard metal finishing media just described. The advantage of soft steel media is that the metal configurations are very repeatable in shape and size, which reduces media lodging problems. This is important when the process needs to reach inside blind features or intricate areas of parts where irregularities might cause media lodging. Zinc forms also are used in this manner.

Preformed steel media shapes differ from the shapes of other media. They are produced in two grades each of balls, ball cones, cones, diagonals, oval balls, diamonds, and serrated pins. The serrated pins provide aggressive cutting, while the others provide polishing and burnishing actions.

As an alternative to steel media shapes, preformed zinc is occasionally used for burnishing operations. Tacks, pins, wire brads or clippings, and nails, mixed with fine abrasive, are sometimes used to remove burrs from small holes and recesses.

By being non-abrasive and non-wearing, steel media, coupled with a good compound containing cleaning properties and a built-in corrosion inhibitor, actually scrubs surfaces and interiors resulting in a most economically efficient removal of both organic and inorganic soils. This method of cleaning is now commonly used to remove a wide variety of soils on many types of materials. Common carbon steels to exotics such as silver and gold are cleaned in vibratory equipment. Systems are able to efficiently remove soils from machining operations, stampings, and headed parts, as well as oxides from zinc, aluminum, brass, copper, and more. This unique scrubbing action and accessibility actively removes metal chips from machining operations, milled grooves, threaded holes, slots, etc., while at the same time removing soil from the parts.

Although steel media is not used to cut down a heavy burr, it is a widely used method for peening or hammering sharp edges to very acceptable conditions. Extremely complicated castings are deburred in large quantities due to the size control and accessibility to all part areas afforded by steel media. Steel media reduces sharpness with such speed and success that the deburring cycle is usually less than 15 minutes.

Ball burnishing, as it is sometimes referred to, is used to produce smooth, mirror-like finishes on parts. Metal surfaces vary greatly, from matte type finishes to smooth, polished types in which surface reflectivity is improved. A matte surface is non-reflective because it has numerous hills and valleys or ridges and grooves. Burnishing with steel media peens down these imperfections and produces smooth and brilliant surfaces. The action in vibratory equipment provides interior action as well as exterior so burnished finishes can be obtained on inside dimensional areas as well as on outside surfaces.

Deflashing or removing flash from certain types of thermoset plastics has been accomplished with steel media for years by leading manufacturers of thermoset electrical components. Because thermoset plastics are non-abrasive they cause no damage to surfaces, and processing time cycles are normally short—usually 7–12 minutes. Complex ceramic insulators with intricate cavities are also successfully deflashed using this process.

Surface modification reduces roughness, surface area, and improves soil and stain resistance in a workpiece. The media pounds down the surface to create uniformity and smoothness. This results in less surface area and less roughness on a part. Also, resistance to soil and stains is achieved because the microscopic peaks and valleys, which entrap the soil on most workpieces, are modified by the pounding action of the media. This application is commonly used for food processing equipment, which requires a high degree of cleanliness.

Steel media is not abrasive by nature, and does not create nor absorb soils. Therefore, it is not likely to cut or scratch workpieces. Since it is not abrasive it will not change the dimension of parts such as investment castings, in which tolerances must be maintained. The media does not create soils. Therefore, workpieces come out extremely clean and no secondary operations are required to clean parts after they are unloaded from a vibratory finishing machine. Steel media is hardened to Rockwell C 60 minimum; therefore, it maintains its dimension and shape with continued use.

Because of the density of mass in steel media—approximately 300 lb per cu ft (4.8 kg per liter)—it delivers very fast finishes in burnishing, deburring, degreasing, and deflashing operations. Cycle times are generally less than 15 minutes. It also has an average life of around ten years. Steel media is too heavy for use in about 50% of vibratory machines. Users should check their machine capabilities before procuring a load of steel media.

Steel media does not wear the lining from finishing equipment, so the cost of relining machines is eliminated. Despite its mass, it can be used to process fragile parts. Small-sized steel media can actually cushion and support parts within the finishing mass.

The attrition rate of steel media is low, but coupled with other losses, most steel media users replace 10% to 25% of what they use each year.

Burnish quality improves as metal media becomes smaller, but the smaller the media, the (considerably) longer it will take to get the surface burnish desired.

6.2.6 Metal Tacks, Pins, Screws, and Brads

Many users have resorted to metal tacks, pins, brads, or screws to finish parts. These provide points and rough edges to reach difficult areas and in general do not present lodging problems. In tumbling operations these do not wear enough to be noticed. They do need to be protected from moisture to prevent rust. Typically they are run dry.

6.2.7 Rubber Forms

Rubber forms that have abrasives bonded in them have been used for deburring and coloring. These are color coded so that users can tell the abrasive size in each form (Enyedy 1955).

6.2.8 Ice-Bonded Media

In 1973 one manufacturer introduced equipment that used ice-bonded abrasive as the media. This prevented the problem of media lodging. A slurry of water and abrasive was cast and frozen into shapes similar to traditional media shapes. Warm water quickly removed any lodged media. The challenge here is to provide enough media and to do so fast enough to beat the heat of friction. In addition the system has to remove the excess water as the media starts melting. Equipment modifications include adding a system that continually circulates a refrigerated coolant to keep the media frozen and a drainage system that maintains coolant flow rates and internal separation to eliminate the need for external cleaning and filtering of the media, which would melt the abrasive. (Anonymous 1973a; Anonymous 1973b).

6.2.9 Dry Ice Media

Dry ice is sometimes mixed with ceramic media to help deflash rubber and plastic parts. This media would be run dry. The dry ice embrittles the plastic and rubber flash, and the ceramic media can then remove it more quickly. It is important to make sure that covers are adjusted to allow the dry ice gas to escape the machine. It is equally important to alert operators that dry ice is in the area and to assure that concentrations do not remove oxygen from the workers' air supply. Another safety concern with this media is the skin burns workers can get if they allow the dry ice to touch bare skin. Cooler temperatures in rooms that use extensive amounts of this may also cause skin rashes or discomfort.

6.2.10 Other Media

Many other media are used for special mass finishing applications. For example, pieces of leather or felt are sometimes used for light burnishing or wiping operations. Nylon media is used for cryogenic deflashing, and rubber-bonded abrasive media for light deburring and smoothing of soft metals. Crushed walnut shells, crushed apricot pits, wooden pegs, pieces of plastic, processed corncobs, and carpet tacks are also in common use in some applications. As noted earlier when hard wood forms, such as pegs, diamonds, cubes or rectangles, are used the hard wood helps to polish the parts.

Walnut shells are used for stamped, formed, or chemically etched thin sheets of brass or beryllium copper[2] (Loschy 1973). Small screw machine parts and jewelry are often processed dry. Walnut shells will impart a high polish while removing burrs. Walnut shell media is produced in a variety of sizes. Any shape of crushed plastics may be effective for removing fine flash. It does not have to be a preformed shape.

Crushed and graded corncobs are usually used to dry parts as they absorb the water from wet parts. This eliminates watermarks or stains that are objectionable on many parts. These cob pieces also help remove oil and grit.

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[2]Beryllium particles cause berylliosis, a serious lung disease. Beryllium copper appears to be a source of the disease, also, and current studies indicate that very minute particles can cause the first impact on the body. In the past users were advised that keeping dust out of breathing air space was the key to prevention. Today there is a belief that small wet particles rubbing on hands or bare skin may be the first trigger. When they handle beryllium copper workers must treat it as a critical carcinogen.

6.3 EFFECT OF MEDIA SHAPE

With a natural or random-sized media that has been crushed and graded to size the best that can be achieved is one point of contact on any shape workpiece. With cylindrical-shaped media, there will always be at least one point of contact, and very often line contact (Fig. 6-6). Triangular-shaped media will also have at least one point of contact, often line contact, and, sometimes, flat area abrasive contact. The more contact the faster the burrs are removed. Generally, flat stamping work can be more efficiently processed with a flat triangular-shaped media.

Screw machine parts and concentric surfaces can never get more than line contact with either the cylindrical or the triangular shape, with most of the work preformed by single points of contact.

Media density runs from 20 lb to 350 lb per cu ft and here is where a lot of trouble starts. Some salesmen will offer, or a purchasing agent will buy, the cheapest media—the media having the least cost per pound. This is rarely the most economical media in terms of cubic feet required in the unit or in terms of media wear rate against stock removal.

When a manufacturer considers lodging costs, rinse quality, wear rates, and cutting rates, some of the so-called low-cost media might cost less if it were placed out in the driveway rather than in the deburring tub! In precision work, often the cost of the media is a fraction of the value of the work in the unit, and less expensive media often means a sacrifice in quality.

The next consideration concerning media and compound selection is *wear rate versus cutting rate.* Harder media will last longer than softer media; however, softer media will probably cut much faster. All plastic, natural, and ceramic media experience wear and, as a result, eventually get smaller. They must be discarded or they will become lodged in holes and recesses, which requires manual removal, and in some instances, scrapping of product.

The sharpness of the abrasive grain determines the stock removal rate. Thus, high cutting efficiency yields a poor surface finish, and a good finish results from poor cutting efficiency. In other words, it is possible that a *dull 60 grit abrasive will produce a finer finish than a sharp l20 grit.*

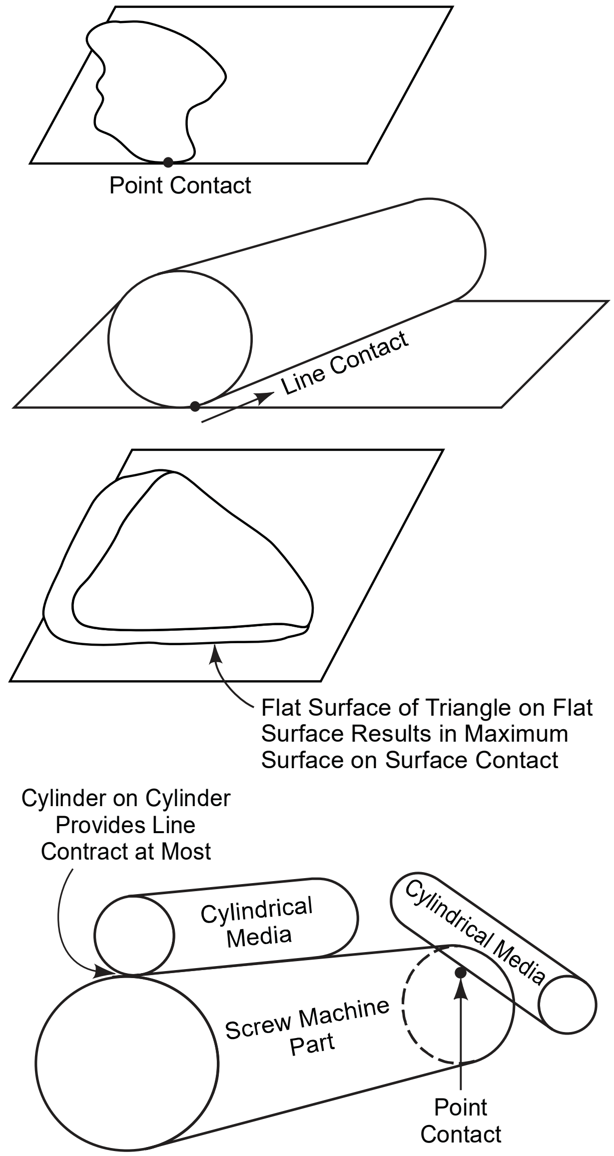

Figure 6-6. Effect of media shape on surfaces available to cut

Abrasive grain size is not always a function of finish; rather it is a matter of cutting efficiency. So stock removal cannot always be related to abrasive size.

Users are sometimes surprised by the weight of large quantities of media, particularly steel balls. Table 6-4 provides some insight into weights of common media.

Cost per cubic foot of media varies dramatically. For example, ceramic media may be purchased for $60–$75 per cu ft; carbon steel balls could be $1100–$1200 per cu ft; nails are $100–$150 per cu ft and corncobs can be found for $4–$5 per cu ft.

6.4 EFFECT OF GRAIN SIZE

When loose abrasive grains are used the stock removed is largely independent of grain size. In studies on abrasives against metal surfaces (not tumbling operations) Moore found the relationships shown in Fig. 6-7 (Avient, Goddard, and Wilman 1960; Moore 1974).

6.5 RATIO OF MEDIA-TO-WORKPIECES

Determining the proper ratio of media-to-workload is essential for economical and successful mass finishing. High ratios reduce the chance for impingement. Any change in the optimum ratio can have a significant effect on the quality of the finishing achieved. Table 6-3 presents typical media-to-part ratios for some commercial applications of barrel and vibratory finishing. The details of how these values are obtained are discussed in Chapters 1 and 4.

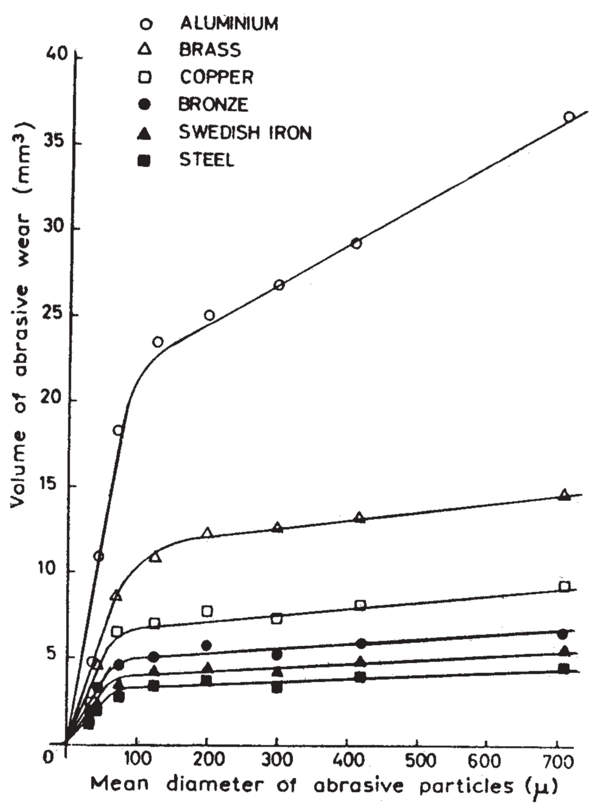

Figure 6-7. Effect of grain size on stock removed for abrasive wear studies (Moore 1974; Nathan & Jones 1966)

6.6 MEDIA ARE NOT ALL THE SAME

Manufacturers often do not make the same sizes, produce identical shapes, use the same materials, nor employ the same processes for preformed shapes. Media may look similar, but no competitive benchmarking data exist to compare cutting action and media costs. Some manufacturers provide comparative data, but there is no standard among manufacturers. In most instances users will pick a shape that will not lodge, yet contacts the desired edges. Few vendors will be found who produce media with such narrow properties. Then users will purchase a sample of some product, try it, and determine if costs and performance are reasonable. For more cost effective needs, users will run competitive samples from several manufacturers. While the results are generally comparable between machines, some machines are designed to be more aggressive than others. Data developed for these machines will not be directly applicable to others, even if they are somewhat similar in type. Valuable detailed observations for testing media to assure valid results are presented in a later section of this chapter. Table 6-5 presents some measured wear and cost data for plastic media.

6.7 CHIP LODGING

Chip lodging is discussed in Chapter 4 as a side effect, and some suggestions are offered for preventing lodging. In addition, the operator will find the following basic considerations are useful for keeping chips from lodging in holes or recesses:

For holes or slots of 1/2 in. (12.7 mm) and above, use a chip size 1/4 in. (6.4 mm) larger than the recess to avoid lodging of irregular chip sizes. If the chip is required to flow through the recess,

Table 6-5. Media cost effectiveness comparison (Bostock 1981)

Media	Attrition Rate, lb/hr	Cost of Media, $ loss/hr	Cutting Efficiency, parts/hr	Media Cost, $/hr	Total Cost (Media & Labor), $/part
A	0.8	1.28	1.42	0.90	out of range
B	0.8	0.99	0.60	1.65	out of range
C	2.0	2.92	0.56	5.21	out of range
D	0.8	1.14	2.50	0.46	1.10
E	0.2	0.28	2.25	0.12	0.83

Media A, B, and C are resin (plastic) media-containing abrasives. Media D and E are aluminum oxide ceramic media. All media were approximately $1^1/_2$ in. arrowhead, tristars, or triangles. Parts were milled aluminum troughs having 0.0005-in. thick by 0.0003-in. high burrs.

then a size 5/16 in. (7.9 mm) smaller than the hole is required. For holes below 1/2 in. (12.7 mm) diameter, a chip size of 3/16 in. (4.8 mm) to 1/4 in. (6.4 mm) larger is used to avoid lodging and 1/4 in. (6.4 mm) smaller is used to flow through freely. If a component has recesses or holes of different dimensions in which media will lodge, a useful method is to fill the holes before processing with a wax having a melting point around 140°F. After processing the wax can be removed by hot water or ordinary degreasing. Another practice is to plug holes with rubber inserts. A variety of shapes and sizes is available.

When parts nestle against each other they mask each other. To avoid this, small springs or inserts can be added to each part to make it stand away from other parts.

Castings and forgings use draft to allow removal from molds. Media can be trapped because of the taper.

One authority notes that if parts are really packed with media it may be possible to remove the media by adding hot water, then soapy water, then running the vibratory finisher at its highest speed (Loschy 1973).

Thermal expansion of the part is another mechanism that may be useful. One user notes (Marcus 1995) that if parts with media lodged in them can be placed in hot water (powdered metal parts often cannot) it may solve the lodging problem. Use the hottest water possible and add compound to prevent corrosion. Let the parts soak long enough to absorb the heat. In some instances that temperature change is enough to release the lodged media. Otherwise it is necessary to shake the parts while they are still hot or the media will not dislodge. Hot oil can be used instead of water, but oil can flame if temperatures are too high.

Some users shoot a nail or other projectile into the lodged media to fracture it. A chisel might work as well, but both of these approaches offer safety concerns as well as significant opportunity to damage parts.

The best method is to prevent the problem. Metal forms like ball cones, pins, and cones resist lodging, but cylinders may be as much a problem as other media materials. Part damage often occurs on precision parts when media has to be picked out, so particular care has to be exercised in planning their deburring.

One user had to protect a critical “V-notch” on a part. By placing a steel rod in the notch and holding it in place with rubber bands, workers were able to protect the critical “V” and no additional protection was needed. On the same part the user cut sponge plugs to push into a tapered hole. The sponge tended to stay within the hole yet was easy to remove (Anonymous 1975).

6.8 REDUCING MEDIA COSTS BY WEAR STUDIES

To illustrate true media costs refer to Figures 6-8 and 6-9. The media used, denoted media A (aluminum oxide) and media B (silicon carbide), were both manufactured by the same company, bound by the same resin, and triangular in shape. The selling price per pound was the same for both media, but media A was 5% more dense than media B and therefore required a bit more to fill the barrel to the proper volume.

Centrifugal barrel equipment was used to determine the rate of edge radiusing on steel cubes by each media.

Note from the test in Figure 6-8 creating a 0.030-in. radius using media A took 33 minutes, while media B took 44 minutes. A 0.040-in. radius took 45 minutes with media A and 78 minutes with media B.

Figure 6-9 shows that wear was less for media A than for media B. In the 45-minute run with media A to get the 0.040-in. (1-mm) radius, the media showed 3.2% wear while media B took 44 minutes to get a 0.030-in. (0.75-mm) radius and showed 5% wear.

In this case the fact that media A was 5% more dense had little effect on costs. Ignoring the slight difference in media used to fill the machine, the cost using media B to generate a 0.040-in. (1-mm) radius is 2.7 times that for media A. For this example 0.040-in. (1-mm) radius required 78 minutes by media B, resulting in 8.6% wear of the media. Using the calculation 8.6% / 3.2% = 2.7 shows that changing to media A cuts media costs by a factor of 2.7—a significant savings!

Also note that a 33-minute increase in production by equipment is possible when media A is used instead of media B. Again, the calculations (78 – 45 minutes = 33 minutes and 33/78 = 42%) show a reduction in run time. Moving to media A cuts media costs by almost a third and provides 42% more open time for machines to do other jobs.

Obviously, testing of media is well worth its cost. The possible savings can be substantial, as was demonstrated in this instance with the combined savings in wear and time.

Evaluation of the use of compounds can also provide savings. Compounds are used to reduce hardness of water, keep fine abrasive particles in suspension, and alleviate corrosion. They must be selected for the proper application.

The general rule with compounds is to determine if they are actually needed. They may be required to degrease and/or improve brightness, but, for short cycles and fast grinding water alone may be equally efficient. Where used, caution should be exercised so that compounds are not overused. In almost every case, it has been found that operators use too much compound, just "to be on the safe side." Additional data are presented in other reports (Southern 1983).

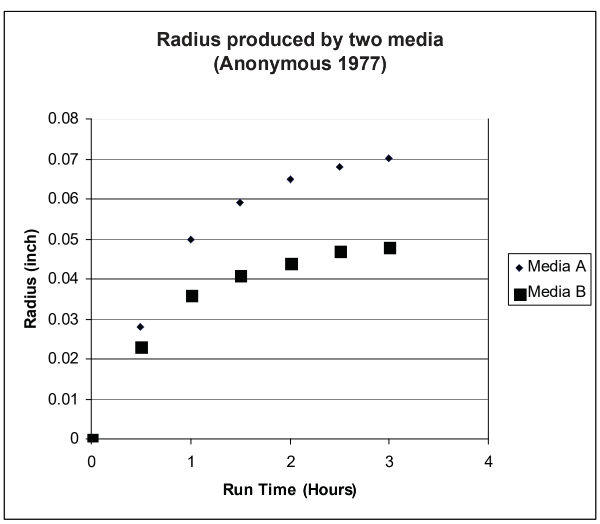

Figure 6-8. Radius produced by media (after Anonymous 1977)

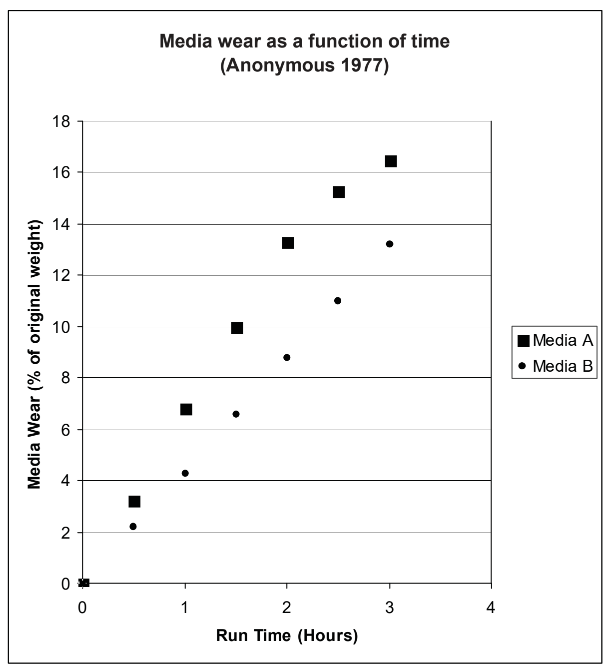

Figure 6-9. Media wear as a function of time (after Anonymous 1977)

6.9 MATHEMATICS OF MEDIA PROPERTIES

There are several media properties that require calculation and measurement. In the following paragraphs some typical calculations for media are presented. A single source for all mass finishing calculations can be found elsewhere (Kittredge 1981b).

6.9.1 Specific Gravity of Media

A material's specific gravity is the ratio of its density (weight or mass per unit volume) to density of water (1 g/ml, metric). It is a quick guide to media quality as well as weight calculations. An easy procedure to determine specific gravity of media follows:

- Take the mass of a number of media pieces to an accuracy of 0.1 g if using over 50 g of media.
- Fill a cylinder with water about 1/2 to 1/3 full, enough to cover the media. Allow the water to drain down the sides of the cylinder. Carefully read the volume. This is *initial volume*.
- Pour the media into a graduated cylinder (one into which the pieces will fit without jamming).
- Allow the pieces of media that adhered to the cylinder sides to slide down. Avoid splashing, tap frequently to help rid the mixture of bubbles.
- Read the new volume. This is the *final volume*.
- Calculate the specific gravity in g/ml:

$$\text{sp gr} = \frac{\text{media mass (g)/(final} - \text{initial vol) (ml)}}{\text{density of water (1 g/ml)}} \qquad (6\text{-}1)$$

Accuracy of these measurements increases as the weight or mass of media increases in a given graduated cylinder.

Specific gravity can be used to determine amount and/or type of abrasive in a product according to the following relationship:

$$\frac{100}{C} = \frac{X}{A} + \frac{100 - X}{B} \qquad (6\text{-}2)$$

where X = percentage of abrasive in the media (which can be determined by ignition of resin-bonded types), A = specific gravity of the abrasive (2.65 for silica or quartz, 3.2 for silicon carbide, 3.9 for aluminum oxide, etc.), B = specific gravity of the binder system (1.2 for most polyester resins, 2.3 for many ceramic binders, etc.) and C = specific gravity of the media.

Note that aluminum oxide is the most popular abrasive in ceramic media.

6.9.2 Bulk Density of Media

Some of the published data on this important property is excellent. Some, however, is not. Good values are necessary in testing media as well as for determining quantity to fill a machine.

An easy procedure uses a "standard container" of a size compatible with the media size and shape and with the availability of a large enough accurate scale. The container also needs to have a flat opening and be able to hold water. For example, a 4-oz bottle might be excellent for small, steel media, but large plastic media would have difficulty fitting through the mouth. The procedure is as follows:

- Tare (weigh empty) the standard container T.
- Pour in the media to be tested with little tamping or shaking, fill and level off the container.
- Weigh the container and the low level of media, L.
- Carefully tamp to settle the media, removing some if necessary. Continue tamping, refill slowly, retamp, refill, etc. several times. Level the top and weigh the high level of media, H.
- Empty the container, fill with water up to the brim, and weigh this, W.

When H, L, T, and W are in pounds:

$$\text{bulk density (lb/ft}^3) = \frac{(H - T) + (L - T)}{2(W - T)} \times 62.43 \qquad (6\text{-}3)$$

And when H, L, T, and W are in kilograms, then

$$\text{bulk density (lb/ft}^3) = \frac{(H - T) + (L - T)}{2(W - T)} \qquad (6\text{-}4)$$

Note these take the average of the loose and tamped weights. In testing media, take bulk density before and after the test to determine how much greater the weight is after the media consolidates.

6.9.3 Wear Rate of Media vs. Speed

Media wear or depreciation rates are usually based on testing in a machine different in speed from the type being used. Sometimes this is because the test is designed for the convenience of the tester rather than to help to the user. In any event, wear rates can be compensated for speed as follows:

$$\text{estimated media wear rate} = R_e = \left(\frac{S_a}{S_t}\right)^2 \times R_t \quad \text{(6-5)}$$

where R_e = estimated media wear rate, %/hr; S_a = actual vibrator speed to be used, rpm; S_t = speed of vibrator at which test is made, rpm; R_t = media wear rate measured at test speed, %/hr.

6.9.4 Hours of Operational Use of Media

The useful life of media often depends on the dimensional changes that occur from when it is new until just before it begins to lodge in parts. This useful life can be estimated from either of the following:

$$H = \frac{\left[1-\left(\frac{F}{I}\right)^3\right]}{R_e} \times 100 \quad \text{(6-6)}$$

or

$$H = \frac{\left[1-\left(\frac{F}{I}\right)^3\right]}{\left(\frac{S_a}{S_t}\right)^2 \times R_t} \times 100 \quad \text{(6-7)}$$

where H = hours of operational use or useful life of the media, F = final or worn dimension of media, in., and I = initial or new media dimension, in.

6.9.5 Media Wear Rate from Dimensional Changes

Rearranging equation (6-6) will allow the wear or depreciation rate of the media to be determined from the change in its dimension with time:

$$R_e = \frac{\left[1-\left(\frac{f}{i}\right)^3\right] \times 100}{H} \quad \text{(for length, width, etc.)} \quad \text{(6-8)}$$

6.9.6 Media Wear Rate from Weight Changes

By weighing accurately 100 or another definite number of pieces of media in brand new condition and the same number of pieces after a known number of hours of use, the media wear rate can be predicted using the following expression:

$$R_e = \frac{\left[1-\left(\frac{f}{i}\right)^3\right] \times 100}{H} \quad \text{(for weight)} \quad \text{(6-9)}$$

where f = final weight of media pieces and i = initial weight of media pieces.

Note that initial and final weights must be in the same units, either grams or ounces. These formulae are more fully explored and discussed in the section on media testing.

6.9.7 Multiple Media Steps

The pressure for increased productivity with reduced costs and improved utilization of equipment makes efforts using multiple media steps more interesting when a large amount of cut-down (stock removal from parts) is involved. A better understanding of these systems is needed.

An empirical relationship has been developed that relates the times involved in multiple step cycles to the total time with one media alone. This equation assumes that it takes α minutes for media A to cut the original surface roughness from as-received down to nearly its minimum; it takes β minutes for media B to reduce the roughness from that point down to the acceptable level; and that γ minutes is the time media B would take to do the whole job. Then

$$\alpha^{3/2} + \beta = \gamma \quad \text{(6-10)}$$

For example, if we let α and β = 30 minutes each, then equation (6-10) gives $30^{3/2} + 30 = 164 + 30 = 194$ minutes[3]. And 194 minutes is over 3 times as long to do the same job. Again empirically, the relationship in a three-step process is:

$$\rho^2 + \sigma^{3/2} + \tau = \upsilon \quad \text{(6-11)}$$

---

[3]To take a number to a power of 3/2, first cube the number, then take the square root of the result. Answer is approx.

where ρ is the time it takes the first media, σ the second, τ the third, and ν is the time the third media could do the cutting all alone.

6.9.8 Conversion of Media Wear Rates

The standard format for media wear rate is *percent per hour* (%/hr). While this value is a popular one, it is often difficult to use. For this reason the easier *pounds per cubic foot-hour* (lb/cu ft-hr) is used. A comparison of ease of use of each of these is best seen with respective examples.

Example 1: Wear rate of media is 0.35%/hr using a 12-cu ft machine. What is total wear?
Solution: Without knowledge of media bulk density, total wear cannot be calculated.

Example 2: Wear rate of media is 0.26 lb/cu ft-hr in a 22-cu ft machine. What is the total wear?
Solution: That's easy: $0.26 \times 22 = 5.72$ lb/hr.

To convert from one system of units to the other:

$$\text{lb/cu ft-hr} = (\%/\text{hr}) \times (\text{lb/cu ft})/100$$

or

$$\%/\text{hr} = 100 \times (\text{lb/cu ft-hr})/(\text{lb/cu ft})$$

where lb/cu ft is the media bulk density from Table 6.4

6.10 TESTING MASS FINISHING MEDIA [4]

Media has an obvious impact on cost reductions, product quality improvements and process time reductions, as well as on the capacity of a system or the efficiency of an operation or department. It can be changed easily. Optimization of the media for a mass finishing process would ideally improve operational costs and reduce the cost of producing each part.

Testing of media is normally done by measuring the wear rate or loss rate of the media per unit time. The faster the media wears out, the more frequently it is necessary to add to it to keep the mass up to its desired level. The *cut rate* or *metal removal rate* is an important function of a media. Surface roughness reduction per unit time or the ultimate surface roughness capability of a media is important when the quality of the surface being finished is critical, as for example in pre-plate finishing. The ability of a media to develop a radius on a metal part or to deburr a metal part to a satisfactory degree may be a primary requirement of the product.

By appropriate testing, then, it is possible to maximize surface roughness reduction versus time, improve process speeds, or determine how much faster-cutting a new potential media might be than an existing one. Or, media wear can be reduced, thereby reducing costs.

6.10.1 TEST VARIABLES

The number of variables involved and of real consequence in the testing of vibratory media is rather extensive. These are discussed below to provide a better understanding of their influence on the test procedure itself.

6.10.1.1 MEDIA

The class or bond of the media (resin-bonded or ceramic-bonded); the type of media within that class (fast, intermediate, or slow cutting); the size, shape, and age of the media—all these are variables. The supplier's nomenclature on type, size, and shape vary and must be known. For example, manufacturers of vibratory finishing media do not agree on the measuring system for angle cut cylinders. Many manufacturers provide diameter of the cylinder and "cut length," while one manufacturer's length dimension is the overall diagonal length of the cylinder.

Age of media is critical when measuring weight loss. Brand new media normally has to be deburred, just like parts do. Weight loss of sharp edges and adherent fragments can be extremely high during the first several hours of operation. This will reduce to steady state conditions in a

[4] This section is taken largely from (Kittredge 1977). Three individuals are historical leaders in educating users in mass finishing. The first was H. Leroy Beaver in the 1950s. The second was William E. Brandt in the 1960s. John Kittredge is the third and his leadership spanned the 1970s through the early 1990s. This section on media testing is a landmark publication for its insight and clarity. It presents all the thoughts users need to accurately understand the implications of media life and cost. J.K., in his paper from which this and other sections were drafted, also acknowledges the support of M.W. Baker in providing the formulas.

short period of time, or should. Age of the media in operating hours, therefore, is a variable as significant or more significant than many others.

6.10.1.2 MEDIA MANUFACTURING VARIATIONS

Quality control of media during manufacture is as important to the user of media as quality control of the parts produced for assemblies. Manufacturing variations in media can account for the success or failure of the product and can account for variations in test results of large magnitudes. For example, excessive porosity or bubbles in a plastic or ceramic media reduce the mass weight of the "chip" and cause excessively high wear rates when this porosity is exposed. Cracks or fragile corners, which break off, create excessively high wear rates, which may or may not be a characteristic of the product. The degree of cure of plastic media is significant. Undercured material will be gummy and will not cut as expected. Excessive cure reduces the integrity of the binder system, causing variations in wear rate as the chip is used because of variations in degree of cure from the external surface to the interior of the chip mass. Changes in degree of vitrification of ceramic media occur if temperature control and time are not uniform in the kiln. Temperature variations in the kiln can cause variations within the product even though fired all at once. Lot to lot variations can be even more pronounced.

To overcome these problems it is normally desirable to determine the specific gravity of the media, which is a good measure of the integrity of the product. A low specific gravity will imply bubbles or other internal defects. A visual inspection of the product will show cracks, fissures, "crow's feet," or other defects from extrusion of ceramic shapes or from the cutting process. Dimensional variations should also be measured because the size of the media, especially in ceramic types, is a function of the wear of the die through which the material was extruded. Normally, a brand new die is designed slightly undersize and allowed to wear slightly oversize. These limits control the dimensional allowance of the product and have an effect on the volume or size of the chip.

Boiling tests for water absorption can be used to measure the integrity of vitrified ceramic media. A combination of specific gravity and ignition of the plastic binder can be used to determine the integrity of plastic media with excellent precision. These data can determine the type of abrasive used in the plastic media:

$$\frac{100}{C} = \frac{X}{A} + \frac{100 - X}{B} \qquad (6\text{-}12)$$

where X = percentage of abrasive in the media, A = specific gravity of the abrasive (2.65 for silica or quartz, 3.2 for silicon carbide, 3.9 for aluminum oxide, etc.), B = specific gravity of the resin (1.2 for most polyester systems), and C = specific gravity of the media or chip.

NOTE: Abrasive *blends* can give misleading results!

6.10.2 Equipment

The type of vibratory equipment is variable in the evaluation of media because of the wide differences in action possible with each type. The size of equipment sometimes has a bearing on results obtained on media evaluation.

Several types of vibratory equipment are available. These include the conventional tub-type vibrator, the tub-type vibratory equipment with dual shafts, the round or toroidal types (several!) and other special varieties. In these types a considerably different action occurs due to the difference in configuration of the chamber, as well as in the orientation of the eccentric weights. Many tub-type vibratory machines are extremely poor in their mixing capability, while some round machines can be excellent (some are not). A tub-type vibratory machine with a center outlet drain and equipped with a system metering compound solution only in the center of the tub will produce a clean band of media in the center of the tub. Dirty media will develop at each end. Mixing is therefore poor. This poor mixing can cause migration of parts or separation of media sizes. This is known as the "end effect," a characteristic of most tub-type vibratory machines. Tub-type vibratory equipment is equipped with equivalent eccentric weight systems on each end of the shaft (or dual shafts as the case may be). Increasing the amount of eccentric weight on the shaft increases the amplitude or displacement of the tub. Amplitude is easily measured by an **Ampli-check**[5] or similar device. It should be recorded, as it is a fundamental characteristic of a machine's operating condition. Speed of the eccentric weight system must also be recorded. If a variable speed drive is used, a strobe light or mechanical tachometer should be used to determine speed of the eccentric weight system. Increasing speed of the eccentric weight system *will* also increase media depreciation rate and media cut rates.

The round machines are better mixing devices because of the three-dimensional influence of the eccentric weight system on the mass. Toroidal or "round" vibratory machines have dissimilar eccentric weights on the top and bottom ends of the shaft, which must be recorded, as must be the angle between them. This angle is identified as either a position number on the top eccentric weight or an angular difference noted on the bottom weight. Direction of the eccentric system rotation should always be opposite to that of the mass flow in this type of equipment

Equipment that has been constructed with different lining materials can influence media depreciation rates. Larger sizes of the same design equipment sometimes do not have the power of the smaller units on a per cubic foot basis, and, therefore, can give lower media depreciation rates. Amplitude and speed characteristics are very helpful in these determinations. The effect of equipment drainage is discussed below.

6.10.3 Solutions Systems

The solution system consists of water and compound metered into the vibratory container and the removal of the spent solution from the tub. The type of compound, its flow rate, the flow rate of water, the concentration of the two, and their removal rate influence media depreciation and cut rates.

The type of compound used in any test work is dependent on the work desired. "Deburring" compounds are those designed to keep media and parts clean, to suspend soil, inhibit corrosion and the like, and, therefore, provide a media which is free cutting and capable of removing metal with excellent efficiency. "Burnishing" compounds, on the other hand, impede the ability of the media to cut and therefore are used to promote a luster on the metal parts, or "color" as it is sometimes called. These products, of necessity, have a significant effect on depreciation rate, reducing media losses to extremely low values.

Concentrations of compound in water depend on the particular compound in question. Most industrial grade compounds used today are effective in concentrations from roughly 1/2–1% by volume. Higher concentrations can impede action or reduce metal removal rates and reduce media depreciation rates. They can dampen down action with excessive foam or excessive lubricity. Both effects alter results.

If drainage of the tub chamber is limited then the solution flow rate must be reduced accordingly. If excellent drainage is provided in the tub, very fast removal rates of solution can be used to remove soil and debris more readily. By the same token, the size distribution of media also influences drainage rate.

Very small media has very small spaces between particles to allow the solution to drain. Very large media has much larger void channels and this permits drainage to occur much more readily. Small random-shaped media is worse than small preformed media in this respect. If the flow of solution is impeded by the media or by the drains, excessive solution will build up in the tub, reducing the action of the media in the vibratory container.

One experimenter wished to eliminate the variable of compound from his test procedure and ran all of his tests in plain water. It was suggested that he verify these results with a very small amount of alkaline deburring compound. Because of the effect of corrosion on the test pieces, he ended up proving that his original body of data, without compound, was meaningless. Vibratory finishing has the unique ability to develop very active metal surfaces. He was using this effect (loss of metal by corrosion) to his disadvantage (He needed compound to prevent the corrosion and to provide accurate production data.) Measurements.

6.10.3.1 TIME OR DURATION OF TEST

How long should a media depreciation test be? The only answer to this question is that it should

[5]See Chapter 10 for an illustration of this 3M Corporation aid.

be sufficiently long to provide reliable and reproducible data and short enough so that the test cost, both in materials and labor, is held to a minimum. This ideal balance is very difficult to achieve in practice, especially in an industrial environment where this is only one of hundreds of priority projects.

Time can be a significant variable in the evaluation of media. As indicated previously, the time of use of media or its age will have an influence on wear rate. This will be shown in an example later. If the test time to be conducted on media that is brand new is selected to be 4 hr, very high media depreciation rates will be measured. This "break-in" period does not give reproducible weight loss data. It is less representative of the media body itself. Thus, a period of this duration would be used only by a manufacturer who had to guarantee wear rates over long periods.

At the other end of the spectrum, much longer test periods (weeks or longer) cause other complications. Media size deteriorates considerably. The volume of the mass is reduced appreciably and must be replenished with new media, as is done in normal commercial operations. The frequency of media addition has an effect on wear rate. The gradual reduction in average size of the particle or piece of media will cause a change in the depreciation rate.

6.10.3.2 MEDIA WEIGHTS

Certain techniques improve accuracy in the weighing of media before and after tests. For media evaluation time periods of less than 24 hours in duration, weighing media wet is the wrong choice; it is error-prone and not reliable. These weights cannot be reproduced with sufficient accuracy to permit their use. Accordingly, media must be dried to insure accuracy and reliability of data. These techniques include the use of rinse aids to sheet off water or develop a uniform film thickness of water, or shaking of media n times prior to weighing, allowing it to drain for a given number of minutes (Controlled drainage procedures cannot be used on short time tests because they are not reproducible). In 3-hr tests of 2-cu ft (57-liter) quantities, a scale accuracy of ±1/4 oz (±7 g) is required. When 200 lb (90 kg) of media is involved, this type of accuracy precludes the use of wet media.

An uncommon effect, but a real one, in media testing can occur in long test periods. It is the effect of the media "compact," that is, the increase in bulk density versus time. As media wears, smaller media worn down will fill the interstices between larger media particles. The effect of this action, assisted by the deburring and radiusing of the media particles, is that the bulk density of the media will increase. More media is required to fill or maintain the level of the vibratory chamber. This media is not "lost," but it is required in order to operate the system at a full level. Media that is angular in geometry shows this effect much more prominently than media that is more rounded or cylindrical. Triangular media will show this more than cylinders will.

As mentioned in a previous section, media weight losses are normally calculated in percentages (i.e., 0.35 lb loss/hr). Weight loss per hour is not as easily used as the less common pound loss per cubic foot per hour (or grams lost per liter per hour). Pounds lost per cubic foot per hour values are immediately convertible to good cost estimates.

6.10.3.3 METAL REMOVAL OR CUT RATE

An important characteristic of any media is its ability to remove metal. Measuring this phenomenon can be difficult, confusing, misleading, or any combination of these. The shape, size, quantity, and composition of the test pieces can cause variations in results. These must be of a size compatible with the weighing mechanism. An analytical balance is preferred on small parts. Massive quantities of steel must be weighed on larger scales with perhaps much less accuracy.

The shape of the test piece is important. One group of investigators recommends the use of spheres. While the use of spheres will eliminate any edge effects or deburring or radiusing phenomenon from occurring on the test piece, it is the poorest possible shape from the standpoint of surface area-to-volume ratio. In other words, a much longer test would have to be run on a spherical piece in order to get reproducible and accurate weight loss measurements than would be needed on a flat or angular piece that had been generously radiused beforehand. Some investigators use sheared test pieces to have a "controlled" burr or edge sharpness with which to work. However, a controlled burr is difficult to produce under the best of circumstances. Well-deburred and radiused parts with a high surface area-to-volume ratio are therefore recommended.

It is often desirable to have more than one alloy represented. Weight loss measurements on aluminum, brass or copper, steel, stainless, and zinc are not always comparable. The metals vary in hardness and toughness. The data are converted to percentage weight losses to eliminate minor variations in initial weight loss of the test coupon. This permits use of sheared pieces that are not dimensionally exact.

6.10.3.4 SURFACE ROUGHNESS

Surface roughness can be accurately determined on metal coupons processed in media. To assure there is accuracy in these measurements, the initial surface of the test coupon should not be too dissimilar from the final surface roughness. If a belt-sanded metal surface is employed and the test time is insufficient to allow the media to remove all scratches, surface roughness readings will be useless. Whenever possible, because of the desirability of having well-radiused test coupons to eliminate deburring from overly influencing test results, the test coupons might be processed in the test or similar media for several hours before use. A good "ultimate" surface roughness capability of the media is then possible.

Media also reduces surface roughness per unit of vibratory finishing time, as shown in Figure 6-1. This idealized curve also shows the minimum surface roughness characteristic of the media under the conditions of the test.

6.10.3.5 DEBURRING OR RADIUS MEASUREMENTS

The SME book *Hand Deburring: Increasing Shop Productivity* includes a chapter on measuring burrs that is too extensive to include here, but Chapter 29 provides the most important elements of burr measurement (Gillespie 2003). Just as is the case for measuring weights, there are many subtleties on burr and edge measurements that should be understood before one undertakes such studies. A manufacturer who makes economic decisions based on observations of samples that do not represent what the situation would be for pieces having real burrs faces the same basic accuracy problems as when estimating for weight, as previously discussed.

Radius measurements can be made with radius gauges or an optical comparator. If sharp edge beginnings are representative of the real parts, then the initial radius should be as close to zero as possible. Surface ground stock, keyway keys, and the like are economical and readily available and provide such sharp edges.

6.10.4 Recommendations for Good Media Test Procedures

The following recommendations are listed somewhat in order of importance.

1. The test procedure must be designed to measure what is most important to the user. Comparative media cut and wear rates may be of no interest or significant value to an individual who is interested in reducing surface roughness of parts. They could be quite in error.
2. Pick a media type, class, size, and shape that are typical for the type of media used in your plant. Media manufacturers should provide media that is a popular and of simple shape and size.
3. The quality of the media to be evaluated should be "average." It should not be specially made by the manufacturer if at all possible, but should fairly represent the normal manufacturing tolerances. After it has been received, it is reasonable to ask the manufacturer to recheck his quality control samples to insure that it does meet his quality control tests fairly. It would be unwise to conduct an enormous amount of test work on a batch of product of questionable quality. Do not assume anything.
4. Equipment size should be kept relatively small. Bench type machines are not recommended because they sometimes operate at higher frequencies or with chambers dimensionally so small that interference can occur just because of the size. Two- to four-cu ft (50- to 100-liter) machines should be the minimum size. The size should not be too great and will depend entirely on the type of weighing equipment available for initial and final weights on the media. Two or more weighings of the media should not be used because this practice

multiplies error. The scale should be able to handle the entire charge at once. Media additions should be weighed in if a long time test is selected. Again, such weightings should be held to an absolute minimum.

Equipment settings should be mid-range or should be the settings normally used. Amplitude should be selected in a mid-range capability of the equipment. A "medium" amplitude is always desired because the equipment will most often be operated under conditions indicated by a medium setting. In round or toroidal equipment, the position of the upper weight or angular difference between the upper and lower weight should also be about mid-range or the upper weight should lead the lower weight by about 45°. If this angular difference were closer to 90°, a high "feed" rate would be developed in preference to a high "roll" rate. It is more reasonable to measure media with both effects occurring simultaneously, unless specific weight settings are required or are always used in the particular operations.

5. Compound concentration should be relatively low, on the order of 1/2 of 1%. A concentrated deburring compound capable of providing excellent corrosion inhibition on all metals present should be used. Flow rates of solution cannot exceed drainage rate. If no other choice is available, between 1 and 2 gal of solution per cu ft-hr (0.13–0.27 liter/liter-hr) is recommended.
6. Media weights should always be dry. A dryer is therefore necessary. The media should be aged for 1 hr or more, depending on the duration of the test and what it was designed for. If a good, average depreciation rate for the media is sought, it is best to break-in that product for at least 8 hr prior to testing. A media manufacturer might select a time period for break-in of only an hour or two so that conservative, high media depreciation rates would be developed, insuring easy compliance to these values in production. Again, the purpose of the test is paramount. Drying of media must avoid any loss of media particles during the drying or transporting operations. Through-feed cob meal dryers can be used if cob meal will not be carried into the media mass in a way that might affect weight. Normally it would not affect weight. Oven drying is also possible, but is not always available.

   The best way to insure accuracy in the weighing of media is to have different operators weigh the same charge of media using the same apparatus at different times. When two or three operators can agree with the result repeatedly, some assurance then exists as to the accuracy of the measurement[6]. If a long time test is to be run it is necessary the tester protect the scale used for these weights from damage during that time. It is frustrating to finish up a week or so of testing, only to find that the scale has been damaged and that no reliability can be given to the weight difference, which is the important measurement sought.
7. Metal removal or cut rates should be conducted on pieces that have been well-broken in and which will not "nest" together during the operation of the machine for the test period involved. Flat pieces should not be used because of nesting and because they can stick to the walls of the vibratory container if that equipment does not have a ribbed lining. Angular pieces, about 1/8-in. (3 mm) thick, 2-in. (50 mm) long with 1-in. (25 mm) legs have been good test choices. When these metal pieces are formed to a 90° angle, they have little or no tendency to nest together. They must be broken in extensively before use—a period of 24 hours in plastic or ceramic media of moderate to good cutting speed is recommended. Surface roughness measurements on these bent angles can be done with excellent accuracy. Because of built-in inaccuracies of deburred pieces, deburring and radius measurements should not be made on the same parts used to test for weight loss.
8. Test time must be long enough to give sufficient weight loss of material to insure an accurate differential weight with the scale

[6]See *Machine/Process Capability Study* (Perez-Wilson 1989) for simple Six Sigma worksheets for calculating measurement repeatability among different operators. Another publication, "Process Control for Burrs and Deburring," adds many insights into the effects of burr measurements (Gillespie 1994).

available. If a great number of tests are to be run, the test time might be set up at 3 or 4 hr so that three or two tests per day can be run. Here again, the requirements of the data developed determine the procedure selected. Tests this short in time require there be much greater accuracy in the weighing.

6.10.4.1 ESTIMATES OF MEDIA WEAR RATE AND THEORETICAL HOURS OF USE

Speed is a common variable in vibratory finishing equipment. Vibratory equipment is available that operates at 1750 rpm, 1200 rpm, and many other speeds. Variable speed equipment further confuses the test speed. Because of this, different researchers will use different speeds. Therefore, having a way to estimate media depreciation rates at one speed when the test is performed at another is valuable.

The forces supplied to a vibratory machine are centrifugal forces through the bearings. In centrifugal force determinations, speed is a squared function, as observed in the following equation:

$$F = \frac{WRN^2}{35{,}270} \tag{6-13}$$

For convenience we gather below some equations previously presented.

$$R_e = \left(\frac{S_a}{S_t}\right)^2 \times R_t \qquad H = \frac{\left[1 - \left(\frac{F}{I}\right)^3\right]}{R_e} \times 100$$

$$H = \frac{\left[1 - \left(\frac{F}{I}\right)^3\right]}{\left(\frac{S_a}{S_t}\right)^2 \times R_t} \times 100 \qquad R_e = \frac{\left[1 - \left(\frac{F}{I}\right)^3\right]}{H} \times 100$$

$$R_e = \frac{\left[1 - \left(\frac{f}{i}\right)^3\right]}{H} \times 100$$

where F = centrifugal force in lb; W = mass of the eccentric weight in lb; R = radius of gyration in in.; N = speed, rpm.

An *estimated media wear rate* can therefore be determined by the equation:

$$R_e = \left(\frac{S_a}{S_t}\right)^2 \times R_t \tag{6-14}$$

where R_e = estimated media wear rate, %/hr; S_a = actual vibrator speed to be-used, rpm; S_t = test speed for the media, rpm; R_t = media depreciation rate at the test speed, %/hr.

The formula has been used to estimate data developed by other investigators, where good agreement with user information has been found. Use of this formula permits test data developed at one speed to be used at any other speed.

In many applications, media is selected as large as possible so as to not damage parts or interfere with separation from the parts. The media is then allowed to wear down to a dimension at which it must be classified out of the machine to prevent lodging. Thus, the media life is based on the dimensions of the media. If the wear rate of the media is known, or can be estimated, the number of hours of operation during which media is in use can be predicted. This, too, is necessary in developing good estimates of media cost. The media is wholly used within the number of hours of use unless another application for the undersize material can be found. Most frequently the prediction is considered to have no value when it is classified (screened out of the useable media) out of the vibratory machine.

The *hours of operational use* of media therefore can be predicted using one of the following formulas:

$$H = \frac{\left[1 - \left(\frac{F}{I}\right)^3\right]}{R_e} \times 100 \tag{6-15}$$

or

$$H = \frac{\left[1 - \left(\frac{F}{I}\right)^3\right]}{\left(\frac{S_a}{S_t}\right)^2 \times R_t} \times 100 \tag{6-16}$$

where H = hours of operational use, F = final (worn) dimension, in.; I = initial (new) dimension, in.; R_e = estimated media wear rate, %/hr; S_a = actual vibrator speed, rpm; S_t = media test speed, rpm; R_t = media wear rate at test speed, %/hr.

Rearranging shows a sometimes more useful expression, *media depreciation rate from chip dimensional changes:*

$$R_e = \frac{\left[1-\left(\frac{F}{I}\right)^3\right]}{H}\times 10 \quad \text{(for length, width, etc.)} \tag{6-17}$$

Note that expression (6-17) is based on changes in chip dimensions: length, width, height, diameter, etc.

For media wear rate from changes in chip weight, the following is used:

$$R_e = \frac{\left[1-\left(\frac{f}{I}\right)^3\right]}{H}\times 100 \quad \text{(for weight)} \tag{6-18}$$

where f = final chip weight, i = initial chip weight, both in grams.

To show the use, validity, and potential problems with this type of analysis, three examples are given.

Example 1

RFHD (the media manufacturer's code for this media): Ceramic media, angle cut cylinder, 1-in. diameter by 1-1/2–in. long run 600 hr in Roto-Finish Spiratron ST-20[7].

It can be predicted that this media would reach a diameter of 1/2 in. From expression (6-15):

$$H = \frac{\left[1-\left(\frac{0.500}{1.017}\right)^3\right]}{0.10}\times 100 = 881\ \text{hr}$$

Note that this is less than 300 hr beyond its existing planned run of 600 hr. The media will reduce to less than 3/4-in. diameter in 400 hr, as predicted from similar calculations.

Example 2

To develop a full size blend of media for high quality finishing, a Spiratron ST-100 was filled with four sizes of RFC (the media manufacturer's code for this media) fast-cutting ceramic media, 5/8 × 7/8, 7/16 × 7/8, 5/16 × 5/8, and 1/4 × 1/2. These were angle cut cylinders of the given nominal diameter × cut length. Regrettably, media samples were not taken on unused material. The following presents chip diameters vs. operation hours. Standard deviations were below 0.0090 in. in all but two cases.

From these data for chip diameter the following table of media depreciation rates can be developed using (6-6). Note that cumulative operating hours are used.

Table 6-6. Measured media wear (Kittredge 1977)

Feature	Size	Units
Initial diameter, average	1.017	in.
Final diameter, average	0.758	in.
Initial chip weight, average	50.60	grams
Final chip weight, average	20.93	grams
Initial chip length, average	1.475	in.
Final chip length, average	1.245	in.

Table 6-7. Calculated media wear rates

	Media Wear Rate, %/hr	Equation
Based on chip diameter	0.10%/hr	(6-16)
Based on chip weight	0.10%/hr	(6-17)
Based on chip length	0.07%/hr	(6-16)

Table 6-8. Media wear for a fast cutting ceramic angle cut cylinders in a large machine (Kittredge 1977)

Run time (hr)	Average chip diameter (in.) after indicated time			
	5/8	7/16	5/16	1/4
27	0.6123	0.4191	0.3253	0.2578
44	0.6043	0.4077	0.3216	0.2457
89	0.5726	0.3436	0.3004	0.2374
259	0.4787	0.3436	0.2618	0.2061

[7]In order to always be able to trace results, users should describe the manufacturer's complete description of media, the manufacturer and location of media production, as well as all the operational details of the machines used.

Table 6-9. Calculated media size wear rate

	Media Wear Rate (percent/hr)				
Cumulative Hours	**5/8 in.**	**7/16 in.**	**5/16 in.**	**1/4 in.**	**Avg.**
17	0.23	0.47	0.20	0.80	0.43
62	0.29	0.33	0.34	0.35	0.33
232	0.23	0.19	0.21	0.21	0.21

Variation and wear rates are higher at the 17-hr and 62-hr times even though media was broken in 27 hr before measuring! A wear rate for this media blend under these conditions of 0.21 percent per hour is reasonable.

Chip weight measurements were also made as noted in Tables 6-10 and 6-11:

Table 6-10. Media weight changes

	Average Chip Weight (grams)			
Time (hr)	**5/8 in.**	**7/16 in.**	**5/16 in.**	**1/4 in.**
27	9.83	4.33	2.25	1.00
44	9.03	3.98	2.06	0.90
89	8 06	3.57	1.72	0.82
259	51.0	2.56	1.23	0.58

Using formula (6-7) and cumulative times, a table of media-depreciation rates can be developed:

Table 6-11. Media weight wear rate

	Media Wear Rate (percent/hr)				
Cumulative Hours	**5/8 in.**	**7/16 in.**	**5/16 in.**	**1/4 in.**	**Avg.**
17	0.48	0.48	0.50	0.60	0.52
62	0.29	0.28	0.38	0.29	0.31
232	0.21	0.18	0.20	0.18	0.19

These data, like those in Table 6-7, show the characteristic reduction in media wear rate vs. time. That they compare so favorably with Table 6-7 lends validity to formulas (6-6) and (6-7).

Example 3

Now that such excellent results have been shown, it is time to note that vibratory finishing is also subject to "Murphy's law." This example shows there can be problems using these calculations:

For this study, RF-90 plastic, fast-cutting triangle, 1-1/4-in. nominal size is used. This media is run in a Spiratron ST-12 with compound. Measurements are made on length (hypotenuse), altitude, and width (between the almost-parallel faces). Initial dimensions (new media) were not obtained. Dimensions are taken at intervals of 1, 2, 3, 4, and 5 weeks, each of 32-1/2 operating hours. Note the following data.

Table 6-12. Dimensional change using triangles

Operating Time		**Average Dimension (in.)**			**Weight**
Weeks	Hours	Length	Altitude	Width	Grams
0	0	—	—	—	—
1	32-1/2	1.0840	0.5290	0.5818	5.50
2	65	0.9746	0.4874	0.5556	4.34
3	97-1/2	0.8306	0.4070	0.5024	2.78
4	130	0.6936	0.3319	0.4589	1.78
5	162-1/2	0.2935	0.1050	0.4054	0.20

Standard deviations are relatively large as can be expected for such cast products. They are greatest for length measurements and, in general, least for width. Values of standard deviations range between 0.010 and 0.054 in. Measurements at 2 weeks are least in this respect.

From the data in Table 6-12, media wear rates are calculated according to equations (6-17) and (6-18).

The great variability noted for week 5 is due to the very small chip size.

Table 6-13. Media depreciation rate for triangle media

Time Interval		**Media Depreciation Rates (percent/hr)**				
Week	Hours	Length	Altitude	Width	Avg.	Weight
2nd	32-1/2	0.84	0.67	0.40	0.64	0.65
3rd	32-1/2	1.17	1.29	0.80	1.09	1.11
4th	32-1/2	1.29	1.41	0.73	1.14	1.11
5th	32-1/2	2.84	2.98	0.96	2.26	2.73

Note that excellent agreement exists only between the average depreciation rates and weight rates. Length and altitude values are significantly higher than width values as can be expected from the geometry of these edges.

Regular or simple shapes are easier to predict than complex ones.

6.10.5 Is a Media Test Really the Answer to the Problem?

No one can fault the investigator for any attempt to reduce costs in the manufacture of his product, especially in these days of continuing inflation and cost-price squeezes. However, many investigators are asking the wrong question. They should be attempting to determine how they can reduce cost for the deburring, surface conditioning, or whatever on each part produced! When this kind of question is answered, the savings in dollars to the user of the vibratory equipment can often be significantly greater than a change in media could ever be. The following examples will illustrate this point.

Is the part being overdone? Is there too much burr removal? If time cycles can be reduced 10% or 20%, media use should be able to be reduced by like percents.

6.10.5.1 USE SIZES THAT CAN BE EASILY SEPARATED

Many times attempts are made to use as large a piece of media as possible to extend its life. However, if this piece of media is so large that it impedes separation of parts from media, it may not be worth the "savings." By using a smaller piece of media to facilitate separation the operator may save up to 10 or 15 minutes per cycle—every cycle.

6.10.5.2 USE FAST CUTTING MEDIA

Use a *faster* cutting media and higher or faster-wearing media to enable use of a continuous cycle, rather than a batch operation. Continuous cycles are often possible without equipment modification in cycle times up to 15 minutes or more, and up to 30 to 60 minutes with equipment modifications. If a required 20-minute cycle is can be reduced to 10 or 15 minutes by use of a faster cutting media, continuous cycles could be considered if the volume of work warrants it.

6.10.5.3 CHOOSE THE BEST MACHINE

Machine capacity is increased 15–20% by operating round equipment with the gate up or raised at all times. The volume of media below the screen deck in these instances is then filled up to make up the increase in capacity. In addition, the "unproductive" separation time is reduced to one cycle per day! Because loading of parts is continuous, separation is continuous, except for the last cycle each day parts may be allowed to remain in the media overnight as it will do them no harm. Continuous cycles offer the ultimate in economy of a vibratory finishing process just as in other automated processes.

6.10.5.4 CHANGE COMPOUND

Improper use of compound can impede the cut or glaze media. Burnishing compounds are designed to do this to ceramic and plastic media, thereby allowing media to develop much lower surface roughness values on metal parts. However, if an operator uses a deburring type of compound, which does not glaze the preforms, much faster cutting is permissible. Media depreciation rates go up considerably, but the reduction in cycle times is much more prominent and more than offsets the cost of deburring type compounds over burnishing ones.

6.10.5.5 ADJUST FLOW RATE

Adjust the flow rate of solution and/or use the flow-through solution system. A coated abrasive belt, which is loaded with grease, cannot possibly remove metal at the same rate as a belt that is kept clean. Grease is applied to the belt to reduce its cut rate and to develop smoother finishes. Keep the solution clean and use a well-designed flow-through solution system to reduce cost.

6.10.5.6 USE PREFORMED MEDIA

An expensive preform can be cheaper than river rock! Years ago a very knowledgeable customer was setting up a new deburring process with river rock, which could be delivered to his plant for about $0.08/lb. No conventional media could begin to compete with this material on a cost per pound basis. This system required that the rock had to be kept below 1.5 in. (38 mm.) in size and larger than about 0.35 in. (9 mm.) to prevent lodging at either of these extremes. It was a continuous process where parts were fed in automatically by conveyor belt from a rough grinding operation to the vibratory machine, processed for 30 minutes on a continuous basis, automatically separated and sent on to a final grinding operation. No operators were to be used, hence a continuous, tie rod media classification system was designed to remove media at about 1/2 in. (13 mm) in size. After several days of operation of the 70-cu ft (2000-L) round vibratory machine, the random rock was being removed at the rate of over 7 cu ft (200 L) per hour! This user then invested in special size ceramic preform in order to maximize the size of an angle cut cylinder that could be used for his application. His costs dropped remarkably. The media wore out at an orderly rate. Because it was a preform it was classified at a predictable dimension.

6.10.5.7 ELIMINATE PRECLEANING OF PARTS

Vibratory systems can clean metal parts very quickly. A synergistic effect is developed between an excellent cleaning compound and the scrubbing action of media to rapidly remove organic and inorganic soils from metal parts. Elimination of a precleaning step prior to vibratory finishing can more than offset the potential cost increase expected by a media change.

6.10.5.8 USE STEEL MEDIA

While media depreciation rate is an important operational cost, it can sometimes be eliminated entirely by the use of steel media. Vibratory steel finishing machines are being used for burnishing, brightening, cleaning, deburring and other applications. Steel is expensive, on the order of $300 per cu ft as opposed to $60 per cu ft for ceramic. But, it can eliminate lodging problems and produce the cleanest parts possible when combined with an excellent compound system. This expensive media has a wear rate that is essentially zero. It reduces costs significantly and makes a beautiful part.

6.10.5.9 CHANGE THE PROCESS

Change the finishing process to reduce the work required on the parts. If one is pre-plate finishing parts down to a 3- or 4-μin. (0.08- or 0.10-μm) finish in order to permit cyanide copper to level adequately for high quality plating, then changing to leveling acid copper can produce outstanding quality parts at higher microinch surfaces. Cycle times in vibratory equipment can be reduced and sometimes faster cutting media can be used. The savings are obvious.

6.10.5.10 BEGIN WITH BETTER PARTS

Poor quality parts require more finishing time. This holds true whether the part is a die casting loaded with defects or a stamping made on dull die. The worse the die becomes, the greater the defects that must be removed and the longer time it will take to do it. A unique advantage of vibratory finishing is its inherent stupidity. It cannot think. It cannot do more work on parts today because they are made poorly than it did yesterday when they were better made. Knowledgeable operators utilize this fact as a very simple quality control tool. Cycles on new dies are set up at 20 minutes and when the progressive deterioration of the die requires over 30 minutes of processing time, it's time to touch up the dies. The economics of this concept can easily be worked out. Electroless nickel on die casting dies produces better surfaces. If this reduces the initial surface roughness of a pre-plate zinc die casting, it will require less finishing time and considerable cost savings.

6.10.5.11 PREVENT MEDIA CARRY OUT

Much media "wear" is not wear at all, but is media that is carried out lodged in the parts. If this is a problem, adjust the size of the media, classify it, or at least return the media to the equipment or to another piece of equipment used on other parts. Do not throw it away and do not carry it all over the plant. Carryout losses also occur during separation. When this happens, screen design changes can be made to effect much faster and more efficient separation. Tie rod screens, for example, will orient media and allow separation of parts that cannot possibly be done on woven wire or square grid screens. Steps can be put into the separation deck to tip over cup-shaped parts.

6.10.5.12 REDUCE SPEEDS

Efficiency of vibratory processes can be improved by reducing speed of the operation. The tendency is to operate variable speed machines at a high frequency in order to get parts done in the greatest hurry. If the capacity of the equipment is available, and if a continuous process is not being utilized, slow down the equipment. The effects of speed on media depreciation rate were shown above. They are significant. Metal removal rates, especially in the deburring type of application, are much less sensitive to speed. By reducing speed by several hundred rpm an almost insignificant change in many deburring cycles will occur while a phenomenal reduction in media depreciation happens.

6.10.5.13 ELIMINATE MEDIA GLAZE

Media should have a sharp surface to cut. When the media is shiny and smooth, or has a slick or sticky feel to it, it is said to be *glazed*. If existing media has a much darker surface than new media it may also be glazed. Just as a glazed grinding wheel does not cut, neither does glazed media. Time cycles can be two to three items longer than necessary when media is glazed. Media glazes relatively easily for six reasons (Marcus 1996):

1) Lubricating film from mold release agents will cause glazing if it is not removed prior to use.
2) Machining coolants containing oils or soluble oils are carried to parts before cleaning. These are converted to nearly insoluble soaps by the alkalinity (frequently potassium hydroxide) of the vibratory compound.
3) Softer, non-ferrous metals are smeared on the surface of the media.
4) Silicates from many compounds control corrosion and act as builders for detergents. The silicate becomes a glaze. It takes a pH above 9 to keep the silicates in solution, and this higher alkalinity can contribute to making the insoluble soaps (detergents).
5) The media used may actually be intended to glaze to provide better burnishing.
6) The machine settings may not be harsh enough to cause the scrubbing action needed to clean the media.

Glaze can typically be removed by running media a half hour with an abrasive compound. Alternately, deglazing compounds are available to do the same cleaning, but they may present waste disposal problems because the pH ranges are above normal, environmentally acceptable, limits for disposal.

Preventing glazing is the best solution. Be aware of compounds on parts that contain sodium metasilicates, potassium silicates, or sodium silicates. They may not affect the operation, but if there were problems these would be the first compounds to investigate. Ask compound suppliers for other solutions. Higher cut, faster wearing media will eliminate the problem.

If deburring work is performed on relatively short cycles and improving overall economics of the operation is desired, evaluate media having better wear resistance for this type of work. It may be found that just changing the *size* of the media will make a greater difference in deburring rate than going through several grades of media.

6.10.5.14 ANOTHER REASON TO TEST YOUR MEDIA

Any serious investigator must test media as required to suit his purposes. Many users of vibratory finishing systems will gain knowledge of their process and valuable cost saving by such effort. It is recommended that *before* such testing is undertaken, more obvious potential cost savings be explored. Many times preliminary work results in remarkable results.

6.11 PRACTICAL HINTS

The following additional suggestions are based on years of experience from many users. These practical hints will save thousands of dollars when used.

- Media represents one of the highest initial costs of mass finishing. Limit the number of different sizes purchased since all unused media need storage, and that requires separate bins and more floor space. It may mean operators have to travel greater distances to do their tasks. The addition of more or different abrasive compounds can readily make up for some loss of variety in media.
- Larger media sizes typically cost less per pound than small sizes (if media is made of small shapes, then many more pieces have to be manufactured to produce the same weight as larger media).
- A large machine, whether barrel or vibratory, of 20 to 30-cu ft capacity can require 1000 to 1500 lb of media. Steel media is much heavier.

Small or delicate parts under 1500 lb of load will be bent or smashed. To prevent mashing and bending, use smaller tub sizes or lighter media.

- To run long very fragile parts, use a multi-barrel (Figure 6-6) and load parts by alternating layers of chips with layers of parts until the barrel is filled. Leave free space (2 in.) at the top front of the machine to allow parts to work correctly against each other. Use less free space for more fragile parts. This approach is widely used for parts with a large diameter-to-length ratio (20:1 ratios, for example).
- To reduce part-on-part damage on large parts in barrel tumbling, add a few large wooden blocks to the load.
- To prevent part-on-part damage while barrel tumbling delicate parts, process the parts in a 50-50 mixture of corncob meal and loose abrasive media; the corncobs will cushion the parts.
- If there is any doubt about what portions of a part are effectively being contacted by media, prior to tumbling coat the parts with a fluorescent trader dye that will be removed by aggressive dry media action. Under ultraviolet light, the clean, bare part areas appear as a deep purple. Areas with incomplete coverage show bits of white indicating where the dye was not removed.
- Polyester media may require a solution clarifier rather than a settling tank to allow effluent to settle out. One published article (Unzens 1981) provides striking evidence that non-petroleum-dependent media clarifies quickly to allow faster discharge into sewer systems compared to polyester media.

Table 6-14. Typical mass finishing ratios of media to part (Kittredge 1981b)

RV Factor*	Ratio by Volume**	Normal Commercial Application
3.0	0:1	No media. Part-on-part. Used for beating off burrs. No media for cutting.
2.5	1:1	Equal volumes of media and parts. Forgings, sand castings. Crude, very rough surfaces
2.0	2:1	More gentle, more part separation, still severe part-on-part damage.
		About minimum for nonferrous parts. Considerable part-on-part contact. Fair to good for ferrous metals.
1.26	4:1	Probably “average” conditions for non-ferrous parts. Fair to good surfaces.
		Good for ferrous metals.
1.0	5:1	Good for non-ferrous metals. Minimal part-to-part contact.
0.63	6:1	Very good for non-ferrous parts. Common for pre-plate work on zinc with plastic media.
0.5	8:1	For higher quality pre-plate finishes.
0.4	10:1	Used for very irregular shaped parts. Exceptional quality.
—	No contact	Absolutely no part-on-part contact. One part per machine or compartment.
		Use doughnut-shaped machine or fixturing.

*The RV factor is a relative measure of process efficiency. A value of 1 represents a typical industrial operation. A lower value indicates a slower process and a process requiring more care of parts. High values indicate a much higher throughput than normal.

**Ratio by volume indicates the ratio of media used per part. A 10:1 ratio implies that typically 10 cu in. of media would be used to finish 1 cu. in. of parts. A 0:1 ratio implies no media is used—parts vibrate against other parts.

6.12 ESTIMATING PARTS PER LOAD

Chapter 1 described how to estimate parts per load. The following is a similar step-by-step process. Table 6-14 provides some recommended ratios of media-to-parts.

1) Determine the cubic inch volume of the part or the volume of a box that would contain the part.
2) Divide 1728 cu in. per cu ft by the part volume to obtain the number of parts that will fit in a cu ft.
3) Calculate the actual volume that can normally be run in the barrel (total barrel volume × load height %).
4) Determine the ratio of parts-to-media that is to run (3:1 is typical; it means 1/4 of the load is parts).
5) Determine the volume of parts that can be run by dividing the actual load volume from step 3 by the percentage of parts to media (1/4 for example in step 4).
6) To get parts per load divide the volume of parts in step 5 by the number of parts in a cu ft (from step 2).

For an example, use the data in Table 1-17. Assume the part is 4.6 in. × 3.7 in. × 2.6 in. So part volume is 44.25 cu in., and so the total box size it would take to hold this would be at least 44.25 cu in. Since there are 1728 cu in. in a cu ft, only 39 parts could fit in a cu ft (1728/44.25 = 39). With a 10.8-cu ft barrel that could only be loaded to 60% of capacity the actual workload would be 6.48 cu ft (10.48 × 0.60). Using 3 times as much media as parts (3:1 ratio), then 3 portions media plus 1 portion parts = 4 portions per load. Thus the parts represent only 1/4 the load, or 1/4 of 6.48 cu ft, that is, 1.62 cu ft (6.48/4). Since 39 parts can fit in 1 cu ft, only 39 × 1.62 = 63 parts will be in the load.

The amount of media needed in this example is 10.48 cu ft × 0.60 full × 3/4 of load is media = 4.72 cu ft of media. From Table 6-6 plastic media weighs an average of 55 lb/cu ft so the machine will require 4.72 × 55 = 259 lb of media. Typically users will load until the eye indicates the approximate correct position, but weighing will be more consistent.

6.12.1 General Media Rules

- Always use a media smaller than the holes and radii that the media is to contact.
- A heavy media will cut faster than a light media of the same composition.
- A heavy media will polish faster than a light media of the same composition.
- Metal burnishing media burnishes quickest and provides the highest luster.
- Steel burnishing media will rust quickly unless protected.
- Never use steel burnishing media with abrasives.
- Never use steel burnishing media in compartments that were used for abrasive cutting.
- Use sanding to remove parting lines, not mass finishing.
- Clean dirty parts before processing to prevent contamination of media and equipment.
- Dull polish over darkened surfaces may be the result of unclean processing.
- Clean foam indicates good processing. Dirty foam indicates a problem.
- For soft metals use light media to prevent part damage.
- Use more media if parts are nicked or dinged in the process.
- Carpet tacks quicken removal of small internal burrs—use 60% media and 40% tacks to start with.
- Miniature media sticks to itself because of surface tension. Use a small amount of corrosion inhibitor and water to lower surface tension.
- To minimize lodging use two sizes of media, but more of the small size.
- Screen media after use to discard undersize media so lodging does not become a problem.
- To generate large radii, deburr the parts in their unhardened condition.
- Use ceramic media for heavy burrs.
- Use less water to cut faster.
- Higher ratios of abrasive in plastic media mean lower binder, which in turn translates into shorter media life.
- Higher ratios of abrasive in plastic media mean lower binder, which in turn translates into faster cutting.
- Finer abrasive grains cut faster and improve surface finish more.

6.13 TROUBLESHOOTING

- If steel burnishing media becomes stained or pitted, it can be improved by tumble grinding using a very fine abrasive such as Vienna lime, and then burnished until the color is restored. Deeply pitted shapes require more aggressive cutting action, probably in multiple stages to reproduce the original surfaces.
- Some operators indicate they are self-tumbling the parts, but they use an abrasive. In fact some of these operations use sand as the abrasive, but sand size is also a crushed natural media size. When "sand" is used, inquire about or state the abrasive size to prevent confusion.
- Use self-tumbling if the only requirement is to remove visible burrs without rounding edges.
- To keep thin flat parts from sticking together from capillary action, add calcined alumina or small glass beads.
- Media shape can be a major cost reduction attribute if it is studied carefully. Some consultants indicate that 25% of the cost savings they make are attributed to proper media configuration. One customer found that he reduced media usage from 24,000 lb/yr to 2000 lb/yr by shape change alone.

Table 6-15 provides some solutions to common media problems in mass finishing.

As we close the chapter we note that despite widespread automation many operations still rely on manual separation of parts from media or classification of media sizes: Operators still use their hands to pick parts off the screens.

Table 6-15. Media-related problems and causes in mass finishing

Problem	Mostly Likely Cause	Solutions
Residues left on parts in recessed areas	Abrasive or burnishing compound that did not dissolve in water.	• Thorough ultrasonic cleaning in hot soapy water. • Use liquid compounds in the burnishing cycle.
Media lodges in holes	Poor choice of media or too rapid media break down.	• Screen the media to remove oversize or undersize particles. • Plug holes with rubber plugs, rubber tubing that expands when tension is released, rubber bands, or nylon line with ends expanded by heat. • Deburr before holes or slots are machined. • Purchase special size/shape media; or purchase special screen sizes for in-house screening of media. • Use sizes of media that will not lodge in holes and recesses. • Do not use irregularly shaped media where lodging is a problem. • Screen the media prior to use if lodging occurs. • Choose a media size/shape that can be screened or separated from the parts.
Incomplete burr removal		• Use larger media. • Run for a longer time. • Increase energy or "G" level. • Use a combination of large and small media. • Manually remove large initial burrs. • Use a more abrasive media compound. • Be sure the media shape is consistent with part geometry. • Use a lighter media if burrs are bent over. • Place the parts in a fixture. • Reduce the water level.

Continued

Table 6-15. (Continued)

Problem	Mostly Likely Cause	Solutions
Surface damage, impingement, or roughness		• Use smaller media or well-worn media. • Reduce the cycle time. • When using two different sizes of media, use more of the smaller size. • Use a less abrasive compound. • Select a more appropriate media shape. • Mask sensitive areas. • Increase the water level. • Reduce the number of parts per load.
Flat workpieces stick together		Use small random shape media.
Parts are distorted	Large media and high energy levels bend precision, thin-wall components	Use small media, low energy levels and short run times.
Long burrs are beaten over		Use plastic media. Use other deburr process.

6.14 ENVIRONMENTAL, HEALTH, AND SAFETY

- Do not mix acid compounds with alkaline compounds or solutions since this can create hazardous pressures and can blow covers and lids off into the operator. Such compounds can also blow the solutions into operators' eyes, faces, or other body parts when machines are opened.
- Check pressure relief valves on barrels or closed containers to prevent pressure and heat build-up that can cause lids to burst free, injuring operators. Always release the pressure before opening the container.
- Provide lifting aids to prevent back and muscle problems as well as to minimize repetitive motion injury. Some companies rotate worker assignments every two hours to reduce the potential for repetitive motion injury.
- Know what metals, plastics, and compounds are being processed in order to prevent dangerous chemicals from entering the waste stream. Make sure that other plant employees also know.

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