Abrasive-belt machines are used to grind, polish, and deburrbar, strip, coils, blanks, stampings, forgings, die castings, and sand castings. There are several configurations of abrasive belt-grinding machines, and belt-grinding equipment is similar to that used for polishing (Fig. 2). In general, the abrasive belt is held between a drive roll and a contact roller. Belt tension determines its torque-carrying ability, and, thus, the power delivered to the grinding zone.

The grinding load is usually applied against the belt under controlled force or pressure. Contact wheels over which the abrasive belt rides provide pressure of the belt against the workpiece. Depending on its hardness, the contact wheel can provide either high unit pressure, hard wheel, or low unit pressure, soft wheel. Selection of contact wheel directly affects the rate of stock removal, the ability to blend in polishing, the surface finish obtained, and cost.

Typical operating parameters for abrasive belt grinding are listed in Table 2. Abrasive belt grinding can use belt speeds from 1400 to 1425 m/min (4600 to 4700 ft/min). Grain size of silicon carbide abrasive varies from 36 to 80 grit size for rough cuts and from 120 to 180 grit size for finishing cuts. For contact wheel abrasive belt grinding, speeds are 1370 to 1980 m/min (4500 to 6500 ft/min). Silicon carbide and aluminum oxide belts (24–80 grit) are used for rough cuts. Figure 3 illustrates the typical range of surface finishes that can be obtained using a given abrasive grade.

An efficient belt-grinding operation uses the coarsest grade that produces an acceptable finish. Depending on the objective of an operation, such as maintaining surface integrity, more than one abrasive grade might be needed. When both stock removal and finish are required, a sequence of abrasive grades is used. The coarsest grade is determined by the amount of stock removed and by the grade and treatment of the aluminum alloy. The abrasive should be the finest possible grade that still removes stock at an acceptable rate so that no excessively coarse scratches are produced. The finishing grade is determined by final finish requirements. If several grit sizes of intermediate grades are skipped, some deep scratches will remain that decrease "buffability." In general, more grades can be skipped in the coarser abrasive grades and when finishing softer aluminum alloys.

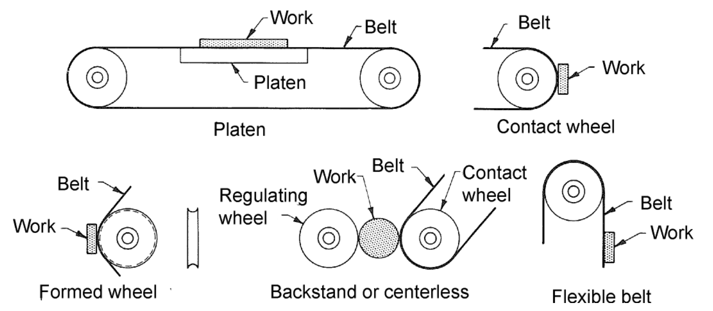

Fig. 2 General types of abrasive-belt polishing methods

Table 2 Operating parameters for abrasive belt grinding aluminum alloys

Material	Hardness, HB (500 kg)	Condition	Operation	Abrasive type	Grain size	Belt speed(a) m/sec	Belt speed(a) ft/min	Contact wheel Type(b)	Contact wheel Hardness, Durometer
Wrought and cast	30–150	Cold drawn, as-cast, and solution treated and aged	Roughing	Al_2O_3, SiC	24–80	25–33	5000–6500	SR, SFR	70–95
			Polishing	Al_2O_3, SiC	100–240	25–40	5000–8000	SR, SFR, B	20–60

(a) Use lower belt speed when good surface integrity is required. (b) SR = serrated rubber. SFR = smooth face rubber. B = buff type. Serrations are usually at a 45° angle, although some heavy stock-removal operations use a 60° angle. Widths of lands and grooves vary from narrow lands and wide grooves for fast aggressive cuts to wide lands and narrow grooves for intermediate and finishing operations, depending on workpiece shape and operating conditions. Source: Ref 5

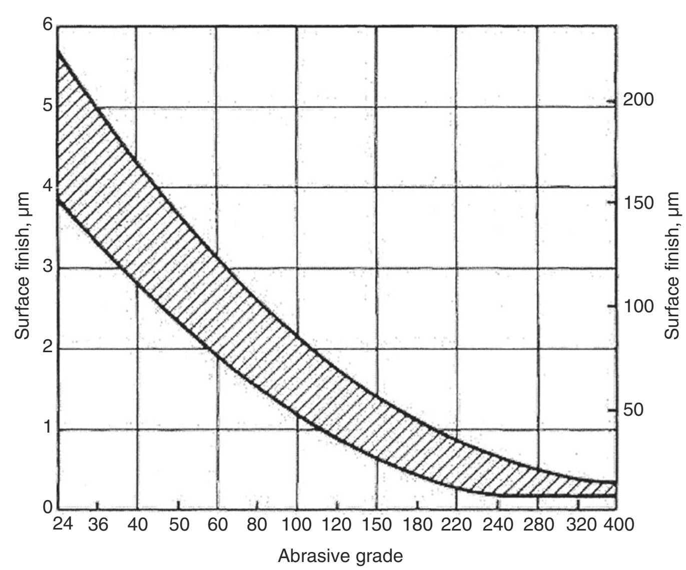

Fig. 3 Surface finishes obtained using varying grades of abrasive belts. Source: Ref 4

Belt Lubricant. Grinding fluids and stick lubricants improve the finish produced by a coated abrasive belt and prevent glazing of the belt. Lubricants used range from water to stick waxes; standard cutting oils and soluble-oil mixtures are often used in high-production belt machines.

Greases cushion the penetrating action of the abrasive into the workpiece and produce finer finishes than are obtained in dry grinding. Although the crest of each grain is free to cut, the grease prevents deep scratches and plastic deformation. Greases are used for the offhand grinding of aluminum die castings. When stock removal is the primary objective, a light grease should be used, preventing the belt from loading but permitting a maximum amount of abrasive penetration into the aluminum workpiece. For a good finish, a heavy grease should be used. Some operations use two types of grease, side by side, on the same abrasive belt. One side is used for a high rate of stock removal, and the other for a finer finish. If the belt becomes loaded despite the use of grease, an application of kerosene frees the belt of embedded particles.

Liquid lubricants are primarily used to prevent belt glazing. When water is used, a rust inhibitor should be added. Soluble oil mixed with water is effective in grinding aluminum if stock removal is the primary objective.

Abrasive Wheel Grinding

This method is preferred for irregular shapes when large amounts of aluminum must be removed quickly and economically. Dwelling at the end of grinding passes should be avoided to prevent the formation of soft spots in harder aluminum alloys. Both solid and setup wheels are used for grinding. Solid wheels are available in a wide assortment of diameters, shapes and widths, and construction. In general, the stiffest wheel cuts most rapidly, producing the coarsest finish. With a given grit, soft wheels offer finer finishes, but reduced cutting rates and plastic deformation of the subsurface workpiece

Conventional abrasive grinding wheels are held together by two types of bond: vitrified and organic. The properties of bonds that are important to the grinding process include the way in which the bond holds the abrasive, the rigidity and/or flexibility of the bond, the wear mechanism of the bond, and the inherent bursting strength or rotational strength of the bond under stress. Wheels with a medium hardness, about 46-grit size, and with a synthetic resin bond are best for roughing. For finishing, wheels of finer grit size (to about 60) and with a vitrified bond are generally are used in best practices.

For grinding aluminum alloys, a silicon-carbide abrasive in a flexible base is generally preferred. Aluminum oxide is seldom recommended, except for piston grinding and in cutoff wheels. Abrasive cutoff wheels for aluminum are usually of aluminum oxide. For wet grinding, which is generally recommended, the bond is usually rubber. For dry grinding, either rubber or resinoid bond can be used.

In cutting off gates and sprues from castings of irregular shape, excessive wheel breakage can occur because of very high pressure on the sides of the wheel. To eliminate this problem and to provide for safe operation, special reinforced, flexible, abrasive wheels were developed. The wheels are manufactured from laminated sheets of cotton fiber filled with abrasive grain and are used for operations ranging from heavy grinding to light sanding: cutting off, sharpening, deburring, and finishing.

Using the recommended speed for a wheel is important, not only from the standpoint of grinding results but also to ensure safety. Stress from centrifugal force increases greatly as wheel velocity increases. The force tending to pull a wheel apart will be four times greater at 3600 rpm than at 1800 rpm.

Tolerances and surface finishes produced on workpiece surfaces and the forces developed during grinding depend to a great extent on the manner in which the grinding wheel is prepared for operation by truing and dressing. Successful use of grinding wheels requires that the wheel is concentric and free of lobes, and truing refers to the process of generating a geometrically correct wheel surface by feeding a single-point or multipoint diamond dressing tool across the rotating wheel surface.

After truing, the wheel surface is generally very smooth. Therefore, the bond adjacent to the grains or grits must be eroded to expose the abrasive grains for efficient grinding. Dressing is the process of eroding the bond matrix in the wheel surface, typically by pressing or sliding an abrasive stick against the wheel surface. Other methods of dressing include exposing the abrasive grains to abrasive slurries and electrodischarge machining.

Polishing

Polishing and grinding have operating similarities, and the terms are sometimes used interchangeably in the trade. However, polishing generally uses abrasive grains finer than 60 mesh. Polishing can be a final finish or an intermediate step between grinding and buffing. However, because aluminum is more easily deformed than many other metals, few aluminum parts require polishing prior to buffing for final finish. In some instances, polishing can be required for the removal of burrs, flash, and surface imperfections. Usually, buffing with a sisal wheel prior to final buffing is sufficient.

Most polishing operations can be performed using either belts or setup wheels. The choice is dependent on factors such as shape and contour of the work, desired finish, and personal preference. Wheels commonly are preferred for irregular shapes and small parts, and abrasive belts for large items with flat and smooth surfaces. Setup wheels can be superior to belts for rough polishing when canvas wheels in a relatively crude setup can be used. For fine polishing work, a specially contoured wheel can be more satisfactory than a belt.

Setup wheels have Two main disadvantages of setup wheels compared with belts are that wheels can be expensive and time, skill, and equipment are necessary for setting up wheels. (The actual time required can be as short as 10 min, but the time is spread over several hours because of intermediate drying steps.) Thus, inventory becomes an important factor when several wheels with different types of abrasives and grit sizes are needed. Considerable operator skill is required for wheel polishing, whereas unskilled labor can be used for belt polishing. Flap wheels have replaced setup wheels in many applications. The use of flap wheels tends to overcome the disadvantages.

Wheel polishing uses wheels considerably softer than those used for grinding. Wheel materials include leather, felt, muslin, and canvas. Cotton fabric (muslin and canvas) wheels are the most commonly used, because of their versatility and moderate cost. The speed of polishing wheels can vary considerably; 1830 to 2440 m/min (6000 to 8000 ft/min) is typically used for soft felt wheels faced with 100 to 600-mesh aluminum-oxide grit.

Fused aluminum oxide is the most widely used abrasive for wheel polishing, because it is hard, sharp, fast cutting, and long wearing. Silicon carbide is also used widely; it fractures when dull, providing new, sharp cutting edges.

Lubricants are extremely important in wheel polishing of aluminum surfaces. Tallow, oil, and beeswax are used, as well as many proprietary materials. The polishing wheel should not overheat to prevent evaporation of the lubricant. Should this occur, aluminum can build up on the wheels, producing deep scratches on the surface and plastically deform the subsurface resulting in strain hardening. Liquid lubricants are gaining in popularity for automatic polishing equipment.

As an example, conditions for wheel polishing die cast aluminum soleplates for steam irons are:

Type of polishing wheel	Felt
Setup time	10 min
Wheel speed	180–2000 rpm
Lubricant	Tallow grease stick

The medium-hard felt polishing wheel is 350 to 400 mm (14 to 16 in.) in diameter, with a 125 mm (5 in.) face. The surface of the wheel is double coated with 240-mesh alumina abrasive bonded with hide glue. Setup time, which is spread out over several hours of operation, totals only 10 min. The polishing wheel can cover 34 to 43 m/sec (6700 to 8460 ft/min).

The soleplates are made of alloy AA380.0, and the sides are polished to remove holes and other surface defects. Buffing follows to produce the required mirror finish. The polishing conditions given in the previous list are based on a production rate of 115 pieces per h per wheel. Each wheel has a service life of 5000 to 6000 pieces.

Abrasive belt polishing advantages include higher polishing speed, larger abrasive area, and less chance of overheating the part, compared with wheel polishing. Belt polishing (belt sanding) is particularly applicable to components having large, flat surfaces, such as extrusions and sheets (Fig. 2). In finishing architectural components, grit between 80 and 120 mesh is used to remove die lines; then, a second belt having finer abrasive (180 to 220 mesh) is used to provide the texture and finish required. Belt speeds between 1400 and 1675 m/min (4600 and 5500 ft/min) result in the finish seen on many entrances, mullions, and windows of monumental buildings. Where a finer texture is required, abrasives up to 600 mesh can be used.

Table 3 gives the conditions and sequence of operations for belt polishing of die-cast steam-iron soleplates made of aluminum alloy 380.0. Ten polishing heads are used to produce a bright finish on the soleplate sides and bottom. Sand castings, inherently rougher than

Table 3 Conditions and sequence of belt polishing for bright finishing 380.0 aluminum alloy die-cast soleplates

				Contact wheel			Belt(a)			
				Size			Size			
Operation	Area polished	Polishing head, No.	Type	mm	in.	Hardness, durometer	mm	in.	Abrasive mesh size	Life, pieces
1	Side	1, 2	Plain face	50 by 380	2 by 15	60	50 by 3050	2 by 120	280(b)	600
2	Side	3, 4	Plain face	50 by 380	2 by 15	60	50 by 3050	2 by 120	320(b)	600
3	Bottom	5	Serrated(c)	150 by 380	6 by 15	45	150 by 3050	6 by 120	120(b)	1200
4	Bottom	6	Serrated(c)	150 by 380	6 by 15	45	150 by 3050	6 by 120	150(b)	2000
5	Bottom	7	Serrated(c)	150 by 380	6 by 15	45	150 by 3050	6 by 120	220(b)	2000
6	Bottom	8	Serrated(c)	150 by 380	6 by 15	45	150 by 3050	6 by 120	280(b)	2000
7	Bottom	9	Plain face	150 by 380	6 by 15	60	150 by 3050	6 by 120	320(b)	2000
8	Bottom	10	Plain face	150 by 380	6 by 15	60	150 by 3050	6 by 120	320(d)	600

(a) Belt speed for all operations was 35 m/sec (6900 ft/min). All belts were cloth; bond, resin over glue. (b) Aluminum-oxide abrasive. (c) 45° serration, 13 mm (0.5 in.) land, 10 mm (0.40 in.) groove. (d) Silicon-carbide abrasive.

permanent mold and die castings, require extensive mechanical finishing to obtain a smooth, bright surface. On sand castings, preliminary operations include rough grinding with bonded-abrasive wheels, to remove surface irregularities after gates, risers, and fins have been cut away. Polishing usually is done using abrasive belts and lubricants to remove the coarse grind marks and smooth the surface. Usually, a two-stage polishing sequence is necessary, beginning with 100 grit size and finishing with 220 grit size, to obtain a surface smooth enough for buffing.

Sometimes, finishing using a dry greaseless compound or a brush-backed sander used without lubrication is advantageous if there is considerable porosity that would entrap lubricants. These same operations can be required for permanent mold and die castings, but to a lesser degree because of their smoother surfaces. The surface of die castings should receive minimum polishing. Only areas such as parting lines and knockout marks should be polished, and only enough to remove surface irregularities. Excessive polishing can alter the surface integrity by removing the dense outer layer of the die cast surface, uncovering subsurface porosity.

After polishing, surfaces should be cleaned to remove residual lubricant and abrasives if they are to be buffed using either manual or automatic equipment. The polishing-buffing sequence yields the smoothest, brightest surface, which is suitable for electroplating and other surface treatments. Many aluminum castings and small stampings are finished by barrel burnishing techniques.

Buffing

The main objective of buffing is to obtain the smoothest possible surface with a high luster. It differs from grinding and polishing in that the abrasive is embedded in buffing compound and is rubbed on the surface instead of being held on the face of the belt or wheel. Also, finer abrasives are used. As a general rule, soft buffs and fine abrasives are used.

Buffing compounds can consist of binders and fluid carriers. Binders can be tallows, fatty acids, hydrogenated fish oils, hydrocarbons, and waxes. Fluid carriers can be water-base and oil-base compounds, or a combination of both. Although liquid and semifluid abrasives can be applied by brushing, dipping, andp[spraying on the surface, the preferred method is to spray the compound directly on the rotating buff. The same abrasives are used in a liquid carrier as in a solid binder

Buffing includes cutting down and coloring. During the cutting-down operation, some aluminum is removed; in the final coloring operation, no aluminum is removed, but a flowing or burnishing action occurs to produce maximum luster. For coloring, an extremely fine abrasive is required, to minimize scratches in the final finish. Fine, soft, white silica is the abrasive generally used for the final coloring operation. Buffs for cut-down usually are made from a heavy, stiff cloth with high thread count (86 to 93), whereas those for color buffing use a lighter-weight, lowerthread-count (64 to 68) cloth. Cloth-muslin buffing wheels commonly are classified as full-disk, bias-type, and sewed pieced buffs. The use of liquid buffing compounds is common for automated, high-production methods.

Selection of a buffing procedure depends mainly on cost, because it is usually possible to obtain the desired results by any one of several different methods. For example, depending on the application, hand buffing might call for the use of equipment ranging from simple, light-duty machines to heavy-duty, variable-speed, double-control units. These machines represent a wide range in capital investment.

Automatic buffing requires custom-made machinery or special fixtures on standard machinery. The size and complexity of the machinery are determined by the required production rates and by the size and shape of the workpieces. High production requires more stations, heavier equipment, and more power. The configuration of the part can be so simple that one buff covers the total area to be finished, or it may be so complex as to require the use of many buffs set at angles and advanced toward the workpiece by cam action.

For cut and color work, buffs are bias types with a thread count of 86/93. For severe cut-down, treated cloth is used with the same thread count. The final color work is accomplished using a buff with very little pucker and a low thread count of 64/64 (see Table 4). A number of procedures that have proved successful for high-luster buffing of specific aluminum parts are summarized in Table 4; others are described in the following examples.

Table 5 gives the conditions and sequence of operations for automatic buffing of wrought aluminum frying-pan covers, which required a specular finish. In another case, the sides of die-cast aluminum frying pans made of AA360 were buffed to a bright finish using an automatic machine with four buffing heads. The buffing wheel of each head consisted of a 14-ply, 16-spoke sewed bias buff with a 430 mm (17 in.) outside diameter, a 230 mm (9 in.) inside diameter, and a 45 mm (1.75 in.) diameter arbor hole. Wheel speed was 1745 rpm, equal to 39 m/sec (7700 ft/min). Each buff was made up of four sections. A liquid buffing compound was applied by one gun per wheel at the rate of 3 g per shot (0.1 oz per shot) for the first wheel, 2.5 g per shot (0.09 oz per shot) for the second and third wheels, and 1 g per shot (0.04 oz per shot) for the fourth wheel. The gun was on for 0.1 s and off for 5 s. The service life of each buffing wheel was 1600 to 2100 pieces.

Die-cast aluminum soleplates for steam irons (Table 6) were buffed to a bright finish on an automatic machine with eight buffing heads. The soleplates were made of AA380.0 and were pre-polished with 320-mesh grit. A liquid buffing compound was applied by one gun per wheel for the first four heads and by two guns per wheel for the last four heads. The guns were on for 0.12 s and off for 13 s. The service life was 72,000 pieces for each buff of the first four heads, and 24,000 pieces for each buff of the last four heads.

Binders in buffing pads and wheels can be tallows, fatty acids, hydrogenated fish oils, hydrocarbons, and waxes. Various binders are combined with a variety of abrasives to satisfy numerous requirements with respect to surface condition, hardness, and type of finish. The function of a binder is not limited to holding the abrasive; it also is a lubricant, preventing overheating of the workpiece and charring of the buff. The lubricating action must be

Table 4 Equipment and operating conditions for high-luster buffing of aluminum products

Product	Size, mm	Size, in.	Type of buffing machine	Buffing wheel: Type	Diameter, Overall, mm	Diameter, Overall, in.	Diameter, Center, mm	Diameter, Center, in.	Diameter, Ply, mm	Diameter, Ply, in.	Thread count	Wheel speed, m/s	Wheel speed, ft/min	Type of compound	Production, pieces per hour
Biscuit pan	340 by 240	13.25 by 9.5	Semiautomatic	Bias	360	14	125	5	410	16	86/93	40	7870	Bar	205
Burner ring	75 diam by 20	3 by .075	Continuous rotary(a)	Radial, vented	(b)	(b)	30	1.2	510	20	64/64	(c)	(c)	Liquid	297
Cake-carrier base	270 diam by 30	10.75 by 1.20	Continuous rotary(a)	Bias	Two 360	Two 14	125	5	460	18	86/93	50	9840	Liquid	278
				Bias	Two 330	Two 13	75	3	50	2	64/68	45	8855	Liquid	. . .
Cake pan	350 by 241 by 65	14 by 9.5 by 2.5	Hand buffing (handles)	Bias	330	13	75	3	50	2	64/68	40	7870	Bar	438
			Semiautomatic (sides)	Bias	360	14	125	5	410	16	86/93	40	7870	Bar	200
Cake pan	200 by 203 by 50	8 by 8 by 2	Semiautomatic	Bias	360	14	125	5	410	16	86/93	40	7870	Bar	127
Cup	60 diam by 65	2.40 by 2.5	Semiautomatic	Bias	360	14	125	5	410	16	86/93	40	7870	Bar	450
Pan bottom	280 by 280	11 by 11	Semiautomatic	Bias	360	14	125	5	410	16	86/93	40	7870	Bar	106
Pan cover	285 by 285	11.25 by 11.25	Semiautomatic(d)	Bias (sides)	360	14	125	5	410	16	86/93	40	7870	Bar	95
				Loose, vented (top)	(e)	(e)	50	2	510	20	64/64	(f)	(f)	Bar	95
Toy pitcher	65 diam by 90	2.5 by 3.5	Continuous rotary(g)	Bias	360	14	125	5	410	16	64/68	50	9840	Liquid	817
Toy tumbler	50 diam by 65	2 by 2.5	Continuous rotary(g)	Bias	360	14	125	5	410	16	64/68	50	9840	Liquid	864

(a) Five-spindle machine; four buffing heads, one load-unload station. (b) Each of the four wheels used had one 330 mm (13 in.) and three 360 mm (14 in.) sections. (c) For 330 mm section, 45 m/s (8850 ft/min); for 360 mm, 49 m/s (9640 ft/min). (d) Two machines, run by one operator. (e) Buff made up of 360 mm, 380 mm (15 in.), and 410 mm (16 in.) sections. (f) 42 m/s (8265 ft/min) for 360 mm sections, 45 m/s for 380 mm sections, and 48 m/s (9445 ft/min) for 410 mm sections. (g) Eight-spindle machine.

Table 5 Sequence and conditions of automatic buffing operations for obtaining specular finish on aluminum frying-pan covers

Operation	Area buffed	Buffing head No.	Buffing wheel: Type	Diameter, Overall, mm	Diameter, Overall, in.	Diameter, Center, mm	Diameter, Center, in.	Diameter, Arbor hole, mm	Diameter, Arbor hole, in.	Ply	Thread count	Density	No. of sections	Speed, m/sec	Speed, ft/min	Life, pieces	Application of compound(a): No. of guns	Cycles, On	Cycles, Off	g per shot	oz per shot
1	Sides (4)	1,2,3,4	Bias, air cooled	430	17	180	7	45	1.75	. . .	86/93	2.4	20	40	7870	40,000	3	0.1	7	0.5	0.02
2	Corners (2)	5,6,7,8	Bias, 20-spoke sewed	430	17	180	7	45	1.75	16	86/93	4	4	40	7870	35,000	1	0.1	7	0.5	0.02
3	Sides (2)	9,10,11,12	Bias, 20-spoke sewed	430	17	180	7	45	1.75	16	86/93	4	4	40	7870	50,000	1	0.1	7	0.5	0.02
4	Sides (2)	13,14,15,16	Bias, 20-spoke sewed	430	17	180	7	45	1.75	16	86/93	4	4	40	7870	35,000	1	0.1	8	0.5	0.02
5	Top	17	Bias, 45° spoke sewed	430	17	180	7	45	1.75	16	86/93	4	15	40	7870	65,000	3	0.1	8	0.2	0.01
6	Top	18	Bias	430	17	180	7	45	1.75	12	86/93	8	18	40	7870	70,000	3	0.1	8	0.2	0.01
7	Top bias	19	Bias	430	17	180	7	45	1.75	12	86/93	8	18	40	7870	70,000	3	0.1	8	0.2	0.01
8	Top bias	20	Bias	410	16	125	5	45	1.75	14	64/68	2	19	37	7300	45,000	3	0.1	8	0.2	0.01
9	Corners (4)	21,22,23,24	Bias	430	17	180	7	45	1.75	12	86/93	8	4	40	7870	65,000	1	0.1	10	0.5	0.02
10	Sides (4)	25,26,27,28	Bias	430	17	180	7	45	1.75	12	86/93	8	4	40	7870	80,000	1	0.1	10	0.5	0.02
11	Top bias	29	Bias	410	16	125	5	45	1.75	14	64/68	2	15	23	4525	80,000	3	0.1	10	0.5	0.02
12	Sides (4)	30,31(b)	Domet flannel	430	17	180	7	70	2.75	20	(d)	(d)	40	20	3900	80,000	6	0.1	11	0.2	0.01
13	Top	32	Domet flannel(c)	430	17	180	7	40	1.625	32	(d)	(d)	24	25	4900	30,000	3	0.1	11	0.2	0.01
14	Top	33	Domet flannel(c)	430	17	180	7	40	1.625	32	(d)	(d)	24	18	3540	30,000	3	0.1	11	0.2	0.01

(a) Liquid Tripoli compound applied to buffing heads No. 1 through 29; stainless steel buffing compound applied to heads No. 30 through 33. (b) Each head buffs two sides. (c) Domet flannel sections interleaved with 180 mm (7 in.) diam disks of Kraft paper. (d) Inapplicable to flannel buff.

controlled, so that it neither leaves a greasy film on the aluminum surface nor serves as a cushion to retard abrasion.

Selection of the proper binder is influenced by factors such as workpiece surface, construction of buff, peripheral speed of buff, type of abrasive, and the finish desired. The binder also must be formulated so it can be removed from the aluminum surface using methods such as degreasing and inhibited alkaline or emulsion cleaning.

The wide range of abrasive types used for buffing aluminum includes tripoli, amorphous silica, crystalline silica, Vienna lime, and a variety of specially prepared proprietary compounds. Hard abrasives, such as tripoli, are used when a sharp, fast cutting action is desired; milder cutting abrasives, such as fine, soft, white silica, are used for bright, mirror-like surfaces. Tripoli is an abrasive most commonly used when cutting down aluminum. It is a natural abrasive and occurs as an amorphous silica with particles that are soft and friable, and absorb oil, grease, and water. When pressure is applied, the particles fracture, providing relatively severe initial cutting, followed by a finer cutting action as the particles wear. This combination of characteristics is not available in any other buffing compound.

Fluid carriers can be a water-base and oil-base compound, or a combination. Selection is based on type of equipment, wheel speeds and the amount of cutting and coloring needed to produce the desired finish. Advantages of liquid buffing compounds include:

- Low labor cost, because it is not necessary to change or adjust abrasive bars
- Reduced waste through the ability to supply the abrasive compound frequently and in small quantities to needed areas
- Capacity to provide a wide range of cutting and coloring speed by adjusting the ratio of abrasive to binder
- Extension of buff life by supplying proper amounts of abrasives at all times
- Easy removal of compounds
- Wide variety of available spray equipment

There is no general agreement on the relative weights to give such advantages; personal preference often influences the final decision.

Although liquid and semifluid abrasives can be applied by brushing, dipping, and spraying on the surface, the preferred method is to spray the compound directly on the rotating buff. Through improvements in liquid abrasive formulations and new spray techniques, the use of liquid buffing compounds has increased for automated high-production methods. In general, buffing requires power of 600 W/cm (2 hp/in.) of width of a 355 mm (14-in.)-diameter buff. Wheel speeds of 1830 to 2440 m/min (6000 to 8000 ft/min) are used for cutting, and 1830 to 2135 m/min (6000 to 7000 ft/min) for coloring.

Satin Finishing

Mechanical satin finishing is an established method used to obtain an attractive surface texture on aluminum hardware items such as knobs, hinges, rosettes, and drawer pulls. Satin finishes are also used for architectural, appliance, and automotive trim. The satin finish results from small, nearly parallel scratches in the aluminum surface, which give the surface a soft, smooth sheen of lower reflectivity than that of polished and buffed surfaces. The soft sheen is the result of fine, irregular lines "scratched" on the aluminum surface. Satin finishes are particularly useful as a texture for castings, cooking utensil interiors, hardware, and various architectural components.

There are numerous ways to obtain a satin finish (Table 7), determined primarily by the shape of the object to be finished and the texture desired. Satin finishes can be applied by fine-wire brushing. Other methods use a greaseless abrasive compound in conjunction with a conventional buffing head, Tampico brush, cord brush, string buff, and brush-backed sander head. Abrasive-impregnated nylon disks mounted like buffs are also used, as are abrasive cloth sections mounted on a rotating hub. All of these methods produce about the same type of finish; the use of any particular one depends on the surface contour of the workpiece. Surfaces of workpieces to be satin-finished should be free of grease and oil, and low contact pressures should be used.

A coarse-lined, or matte, texture can be produced by applying a rotating wire brush to the aluminum surface. The wire can be stainless steel, steel, nickel, brass, and nickel silver, 0.076 to 0.381 mm (0.003 to 0.015 in.) in diameter. Stainless steel is preferred over other metals. Stainless steel wires are recommended, because other metals such as brass and steel can become embedded in the aluminum surface, producing discoloration and corrosion, and can interfere with subsequent electrochemical process. If brass- and steel-wire wheels are used, the embedded particles can be removed by immersing the work in a nitric acid solution (1 part water to 1 part acid by volume) at room temperature.

Finish fineness varies directly with the size of the wire used in the brush. Wire wheels 25 to 30 cm (10 to 12 in.) in diameter are preferred. Wire brushes must be kept free of oxide and accumulations of aluminum particles. This is accomplished by frequently bringing a pumice stone or soft brick in contact with the rotating brush. A common wire brushing setup consists of a 250-mm (10-in.) diameter wheel having a surface speed of about 8.0 m/sec (1575 ft/min) and wires 0.4 mm (0.015 in.) in diameter. Undue pressure on a rotating wire wheel will bend the wires and cause excessive tearing of the aluminum surface.

Wheel speeds of 365 to 700 m/min (1200 to 2300 ft/min) are commonly used for wrought products; considerably lower speeds of 135 to 185 m/min (450 to 600 ft/min) are used for castings. Pressure of the part against the wheel is light to avoid tearing the aluminum surface. For uniform results, grease and dirt must be removed from the aluminum surface before brushing, either using a mild alkaline etch or by rubbing with a lime and whiting mixture. When certain softer wire brush wheels are used, the fine wires may become bent. This condition can be remedied by reversing the wheel on its shaft.

Table 6 Automatic bright-finish buffing of AA 380.0 soleplates

			Buffing wheel										Application of compound(b)		
					Diameter(a)					Speed					
					Overall		Arbor hole								
Operation	Area buffed	Buffing head No.	Type	Size	mm	in.	mm	in.	No. of sections	m/sec	ft/min	Life, pieces	No. of guns	g per shot	oz per shot
1	Side	1,2	Sisal	10 mm (0.40 in.) spiral sewed	410	16	40	1.5	2	37	7300	72,000	1	0.5	0.02
2	Side	3	Bias	16-ply, 20-spoke sewed	430	17	45	1.75	2	40	7870	72,000	1	0.5	0.02
3	Side	4	Bias	16-ply, 20-spoke sewed	430	17	45	1.75	2	40	7870	72,000	1	0.5	0.02
4	Top	5	Sisal	10 mm (0.40 in.) spiral sewed	410	16	45	1.75	15	37	7300	24,000	2	3.0	0.1
5	Top	6	Sisal	10 mm (0.40 in.) spiral sewed	410	16	45	1.75	15	37	7300	24,000	2	3.0	0.1
6	Top	7, 8	Bias	16-ply, 20-spoke sewed	430	17	45	1.75	10	40	7870	24,000	2	3.0	0.1

(a) All wheels had 180 mm (7 in.) diam centers. (b) Proprietary liquid compound was used. Cycle time: 0.12 s on, 13.0 s off

Table 7 Methods, equipment, and conditions for mechanical satin finishing of aluminum

	Suitable equipment			Speed		
Method	Buffing lathe	Portable power head	Power required	m/sec	ft/min	Lubricant
Wire brushing(a)	Yes	Yes	(b)	6–11	1200–2160	None
Sanding with brush-backed head(c)	Yes	No	(d)	900–1800 rpm	900–1800 rpm	Optional
Tampico or string brushing(e)	Yes	No	(b)	15–31	3000–6100	Pumice(f)
Finishing with abrasive-coated cloth(g)	Yes	Yes	(d)	31–36	6100–7100	Optional
Finishing with nylon disks(h)	Yes	Yes	(i)	23–33	4500–6500	Optional
Buffing with compounds(j)	Yes	Yes	(b)	15–26	3000–5100	(k)

(a) 305 mm (12 in.) diam brush of stainless steel wire 0.125 mm (0.005 in.) in diameter. (b) 1 hp per 25 mm (1 in.) of brush width. (c) Using 601.75 to 6001.75 mesh abrasive cloth loadings. (d) 1 hp per head. (e) 300 mm. (12 in.) diam brush. (f) With oil or water; emery cake can also be used. (g) Cloth is mounted radially on rotating hubs; coated with 501.75 to 3201.75 mesh emery abrasive. (h) Disks impregnated with silicon carbide abrasive, coarse to ultrafine. (i) 0.25 hp per 25 mm (1 in.) of disk width. (j) Greaseless satin-finishing compounds containing aluminum oxide abrasive (200 or 240 mesh) used with unstitched or loosely stitched buffs (360 mm, or 14 in.) or with string brush. (k) Dry, or with buffing compound or grease stick

If satin-finished parts are to be anodized, etching or bright dipping should not precede anodizing, because the satin appearance will be lost. Cleaning treatments that do not etch or that only slightly etch the aluminum should be used before anodizing. Wire-brush finishes are dull gray in color after anodizing; the surface may be nonuniform due to variations in the application conditions. Factors contributing to nonuniform finishes include width of wheels, uneven wear and bending of individual wires, and uneven pressure. Nonuniformity is noted particularly on large, flat areas; wire-brush finishes are not recommended for such surfaces.

Other mechanical satin-finishing treatments include brush-backed sanders, buffing wheels with various grades of greaseless satin finishing compounds, and abrasive impregnated nylon disks. If matte surface textures are required, fine sand-blasting and wet-blasting techniques are used. These methods usually produce a more uniform texture than scratch brushing, and are much more adaptable to flat surfaces.

The satin finish processes in which a greaseless abrasive compound is used are essentially dry. Water is required to soften the binder in the abrasive compound so it will adhere to the surface of the buff. After the binder dries, the buff is ready for operation. At this stage, a lubricant, such as a buffing compound or tallow, can be used to produce a higher reflection

The brush-backed sander head consists of a series of 12 to 32 brushes, interspaced with an abrasive-impregnated cloth and mounted radially on a wheel. The brushes serve as a cushion for the abrasive and for the workpiece. Construction of the brush-backed sander enables flat, formed, curved, and irregular shapes to be finished without lubrication. Abrasives used cover a wide range of grit sizes, from fine for satin finishing, to coarse for polishing, grinding, and even deburring. Wheel speeds of 1200 to 1800 rpm are considerably lower than those used with other polishing wheels. The device is sometimes called a soft head. Higher speeds can straighten out the brushes, which may plastically deform and strain harden the surface, whereas at slower speeds, the head "softens" with substantially more "give," which enables polishing contoured parts.

Numerous types of disk sections can be used, as are cloth buffs, to form almost any width. The density of the assemblies is controlled by the compressive force of the end pieces. Low-density abrasive carriers are applied for satin finishes, especially adaptable to irregular shapes. They use the open-web structure of nylon fiber, which serves not only as the body of the material, but also as a support for the abrasive. These materials are offered in most commercial forms, such as disks, wheels, brushes, flat sheets, and belts, and in various degrees of coarseness, ranging from ultrafine to coarse polishing. Most widely used abrasives are silicon carbide and aluminum oxide in a heat-resistant resin binder. Lubricants, which serve as a coolant, can be used to prevent softening of the nylon, which melts at 250 °C (482 °F).

Barrel Finishing

Barrel finishing is a low-cost method used to smooth sharp edges, impart a matte finish, and prepare surfaces for anodizing, painting, and plating. Many small aluminum stampings, castings, and machined parts are cleaned, deburred, and burnished by barrel finishing. In most instances, the main objective is deburring and/or burnishing, with cleaning being an unintended benefit of the treatment. Deburring sometimes is the final barrel operation, but more often it is followed by burnishing to obtain a smoother finish or one that is better suited to anodizing and plating. Parts that have only been deburred are often painted. Burnished parts are frequently anodized for protection.

Small aluminum parts are sometimes tumbled dry in media such as pumice and hardwood pegs, hardwood sawdust, and crushed walnut shells to remove burrs and improve the finish. However, this method is relatively inefficient compared with the more widely used wet process.

All aluminum alloys can be safely finished using wet barrel methods. Limitations imposed by workpiece size and shape are essentially the same as for steel and other metals. There are two general areas in which wet barrel finishing of aluminum parts is more critical than in processing similar parts made of steel. First, there is danger of surface contamination by ferrous metals caused by the use of either a steel barrel or a steel medium. Second, the extent of the acidity or basicity (i.e., the pH value) of the compounds is more crucial when processing aluminum, because aluminum alloys are susceptible to etching by both acids and alkalis, and because gas generated during chemical attack can build up pressure in the barrel and cause serious accidents. Barrels must be vented when processing aluminum. Compounds that are nearly neutral (pH value of about 8) are recommended, although some alloys can be safely processed in compounds having a pH value as high as 9.

Barrels used for aluminum are basically the same as those used for processing steel. However, barrels made of steel and cast iron should be lined with rubber or similar material to prevent contamination. A preferred practice is to use specific barrels exclusively for processing aluminum.

Deburring is performed by tumbling the work in a nonlubricating compound that contains abrasives. In most instances, media also are used to cushion the workpieces and increase the abrasive action. Synthetic detergents mixed with granite fines or limestone chips are usually preferred as the compound for deburring aluminum; aluminum oxide and silicon carbide are not desirable because they leave a smudge that is difficult to remove. Water levels completely covering the mass are used during deburring to assist in maintaining fluidity of the mass and to help prevent the medium from becoming glazed and losing cutting action. Deburring can also be accomplished by using vibratory units with synthetic abrasives.

Barrel burnishing is used to produce a smooth, mirror-like finish on aluminum parts. Bright dipping immediately prior to burnishing aids in producing desired results. Other preliminary treatments also are helpful in specific instances, particularly for cast aluminum parts. One of these pretreatments entails etching the castings for 20 s in an alkaline solution at 80 °C (175 °F) and then dipping them for 2 to 3 s in a solution consisting of 3 parts by volume nitric acid (36° Bé) and 1 part hydrofluoric acid at 20 to 25 °C (70 to 75 °F).

The principle of barrel burnishing is to displace surface grains of aluminum, rather than to deform and shear layers of grains of aluminum from the surface. Burnishing compounds must have lubricating qualities; soaps made especially for burnishing are usually used and are readily obtainable. Many of them have a pH of about 8, although more acidic materials can be used.

When burnishing aluminum, the pH value of the burnishing compound must be closely controlled. This is accomplished by frequent titration of the compound, followed by the addition of small amounts of borax or boric acid as needed. Steel balls and shapes are the most commonly used burnishing media. Several examples of conditions used in barrel finishing applications are detailed in Table 8 Note that deburring and burnishing are sometimes accomplished in a single operation.

Self-tumbling is an effective means of cleaning, deburring, and burnishing small aluminum parts. Procedures for self-tumbling are basically the same as those for other methods of barrel finishing, except that the parts themselves serve as the medium. Compounds for self-tumbling of aluminum should be of nearly neutral pH value, and oxides should be removed from the aluminum parts before tumbling. The size and shape of the parts usually determine whether self-tumbling is suitable. Interior surfaces receive little or no action during self-tumbling.

Vibratory finishing is a newer method used for deburring and burnishing metal parts. When applied to aluminum parts, compounds and media are subject to the same restrictions as discussed previously for conventional barrel finishing.

Abrasive Blast

One of the simplest, most effective method for cleaning aluminum surfaces is by blasting

Table 8 Conditions for wet barrel finishing of aluminum products

Product	No. of pieces per kg	No. of pieces per lb	No. of pieces per load	Cycle time, min	Barrel speed, rpm	Medium description
Clean, deburr and brighten in rubber-lined steel, single-compartment drum, 560 mm (22 in.) diam, 760 mm (30 in.) long.(a)						20 kg (50 lb) of 3-mm (0.125-in.) steel balls per load with parts and 154 g (5.5 oz) of burnishing soap per load
Percolator spout	60	130	630	20	33	
Measuring spoon	20	50	750	20	33	
Flame guard	40	90	1500	15	33	
Leg	35	80	2700	30	33	
Toy spoon	80	180	5000	17	33	
Handle	105	225	5800	25	33	
Deburr and brighten in double-compartment drum. Rubber-lined steel drum each compartment 740 mm (29 in.) long, 915 mm (36 in.) in diameter.(b)						*Medium in deburring compartment*: 2 kg (5 lb) of burnishing soap and 365 kg (800 lb) of No. 4 granite chips *Medium in burnishing compartment*: 0.9 kg (2 lb) of burnishing soap and 680 kg (1500 lb) of 3-mm (0,125–in.) steel balls
Die cast handles	11	25	600	120	15	
Burnish to high gloss in Single-compartment drum, 1.5 m (5 ft) long, 1.2 m (4 ft) in diameter.(c)						2040 to 2270 kg (4500 to 5000 lb) of steel balls 3, 6, and 8 mm (0.125, 0.250, and 0.312 in.) in diameter, and 2 and 3 mm (0.0625 and 0.125 in.) steel diagonals with 5 kg (11 lb) of alkaline burnishing soap (pH 10);
Die cast housing	5	11	60	45	14	

(a) Processing cycle: load drum with medium cover load with water at 65 °C (150 °F); rotate drum for specified time; unload, rinse, separate parts from medium; tumble dry parts in sawdust for 4 min. (b) Load deburring compartment with parts, compound, and medium; cover load with cold tap water; rotate drum for 1 h; unload, and rinse with cold water; separate parts and medium. Transfer parts to burnishing compartment; add burnishing compound and medium cover load with water at 70 °C (160 °F) and rotate drum for 1 h; separate parts and medium, and rinse parts in hot water and then in cold water; spin dry in a centrifugal hot-air dryer. (c) Load drum with parts (parts are fixtured, to prevent scratching) with medium and burnishing soap.; cover load with cold tap water; rotate drum for 22.5 min in one direction, then 22.5 min in reverse direction; rinse and unload; dip-rinse parts, and hand wipe.

with dry nonmetallic or metallic abrasives. Although this method is typically associated with cleaning aluminum castings, it is also used to prepare surfaces of other product forms for subsequent finishes, such as organic coatings. In addition to cleaning, blasting is used to produce a matte texture for decorative purposes.

Abrasive blasting is an efficient method to remove scale, sand, and mold residues from castings. Because castings typically are thick, they generally suffer no distortion from the process. Blast cleaning of parts with relatively thin sections is not recommended, because such parts are readily warped by the compressive stresses that blasting sets up in the surface; coarse abrasives can wear through thin aluminum sections. Typical conditions for dry blasting with silica abrasive are given in Table 9

Table 9 Conditions for dry abrasive blast cleaning of aluminum products with silica

Grit size	Mesh	Nozzle diameter, mm	Nozzle diameter, in.	Nozzle to work(a), mm	Nozzle to work(a), in.	Air pressure, kPa	Air pressure, psi
20–60	Coarse	10–13	0.375–0.5	300–500	12–20	205–620	30–90
40–80	Medium	10–13	0.375–0.5	200–350	8–14	205–620	30–90
100–200	Fine	6–13	0.250–0.5	200–350	8–14	205–515	30–75
Over 200	Very fine	13	0.5	200–300	8–12	310	45

(a) Nozzle approximately 90° to work.

Washed silica sand and aluminum oxide are most commonly used for abrasive blast cleaning of aluminum alloys. Steel grit is sometimes used, and because of the fragmenting characteristics of silica, is often preferred. It also has a longer life, which lowers cleaning costs. However, when an aluminum surface is blasted using grit, steel particles become embedded, and unless they are removed by a subsequent chemical treatment, they will rust and stain the surface. It is good practice to remove particle contamination with a nitric acid pickle to prevent degradation of corrosion resistance. A 20-min soak in 50% nitric acid solution at ambient temperature dissolves embedded and smeared iron particles, but it does not remove silica and aluminum oxide. When aluminum is blasted with No. 40 or 50 steel grit, a 9.5-mm (0.375-in.) diameter nozzle and air pressure at about 275 kPa (40 psi) are commonly used. Organic materials such as plastic pellets and crushed walnut shells also are used to blast clean aluminum, often for the removal of carbonaceous matter.

Stainless steel shot is sometimes used for cleaning aluminum surfaces. Shot blasting is used as a preliminary operation for developing a surface with a hammered texture. An attractive finish is produced when this textured surface is bright dipped and anodized. In addition, the varying degrees of matte texture that can be produced by blasting offer many decorative possibilities. Blasting is often used to produce the maximum diffuseness of the reflectivity of a surface. For example, aluminum army canteens are blasted as a final finish to reduce glare. Glass bead blasting offers another approach to cleaning and producing diffuse surfaces.

Sandblasting using a fine abrasive produces a fine-grain matte finish on wrought and cast aluminum products. For plaques, spandrels, and related decorative architectural applications, sandblasting the background and polishing or buffing the raised portions of the surface produces an effect known as highlighting.

The matte finish produced by abrasive blasting is highly susceptible to scratching and to staining from fingerprints. Therefore, matte-finish surfaces usually are protected by an anodic coating or clear lacquer. Anodizing is the more popular protective treatment, because it does not alter the original texture of a surface. Clear lacquers smooth out roughened surfaces and produce various degrees of gloss, which can be undesirable. Anodizing of a blasted aluminum surface results in a gray color because of embedded abrasive particles in the surface. This color frequently is nonuniform because of variations in blasting conditions, such as nozzle-to-work distance, direction, and movement of the nozzle, and air pressure.

Blasting conditions can be closely controlled by the use of specially designed equipment. Uniform movement of the workpiece on conveyors, established nozzle movement, constant velocity of the abrasive, and controlled size of grit contribute to better color uniformity of subsequently anodized surfaces.

The nonuniform appearance that results from blasting can be corrected by bleaching prior to anodizing. Bleaching is done by deep etching in a solution of 5% sodium hydroxide at 40 to 65 °C (100 to 150 °F) to remove aluminum that contains embedded abrasive. Some trial and error might be necessary to determine etching time for specific conditions. If the surface is not etched enough, a mottled appearance can result. Embedded abrasive can also be removed using a solution of nitric acid and fluoride used at room temperature.

Care should be exercised when selecting the aluminum or aluminum alloy to be sandblasted. For example, alloy 1100, which contains 99% Al, provides a transparent anodic finish; alloys rich in manganese, silicon, and copper, by comparison, are colored when anodized. Alloy segregation can occur in high-magnesium alloys, and pitting results unless special pretreatments are used. Table 10 lists several typical applications for abrasive blast cleaning of aluminum products, indicating the type and size of abrasive used and typical production rates.

Wet blasting mixes a fine abrasive with water to form a slurry that is forced through nozzles directed at the part. Abrasive grit sizes from 100 to 5000 mesh can be used. Wet blasting is generally used when a fine-grain matte finish is desired for decorative purposes.

An attractive two-tone finish on appliance trim can be obtained by contrasting a buffed finish with a wet-blasted finish. Aluminum firearm components and eyeglass parts such as frames and temples often are wet-blasted to produce fine matte finishes. In these applications, anodic coatings, either plain or colored, are used to protect without distorting the intended surface texture.

Typical wet blasting procedures are listed in Table 11. Wet blasting is also used to prepare surfaces for organic or electroplated coatings. Ultrafine glass bead blasting is an alternative to wet blasting.

Lapping And Honing

Lapping and honing techniques apply precision finishes where smoothness and dimensions are of prime importance. These techniques are of special interest in treating aluminum parts that have received hard anodic coatings. Typical tolerance and finish capabilities are:

Finishing process	Tolerance, mm	Tolerance, in.	Finish, µm	Finish, µin.
Lapping	<0.5 µm	<20 µin.	0.025–0.1	1–4
Honing	0.5-1.25 µm	20–50 µin.	0.25–0.5	10–20

In lapping, the surface being finished is rubbed against a mating metal form, called the lap. Aluminum oxide, silicon carbide, and diamond grit abrasives (320 to 600 mesh or finer) are used in conjunction with suitable lubricants. Methods used for lapping aluminum are the same as those used for other metals. However, because similar finishes often can be produced using other methods at less cost, lapping is seldom used. In one application, a hard-anodized aluminum part (surface hardness equivalent to 65 HRC) required removal of 0.005 mm (0.0002 in.) from the three lands to produce a finish of 0.025 µm (1 µin.). Diamond abrasive (8000 mesh) in a paste vehicle was used for both centerless roll lapping and lapping in a two-plate machine. The roll lapper, at a rotation speed of 100 rpm (large roll) and a stroke speed of 50 mm/min (2 in./min), produced ten parts per hour. The two-plate machine, which had upper and lower cast iron laps 405 mm (16 in.) in diameter and 75 mm (3 in.) thick, lapped 1000 parts per hour.

Honing is similar to lapping, but uses a honing stone instead of a metal lap. For rough honing, 150 grit is used; grit 500 mesh or finer is used for final honing. Aluminum alloys are honed using methods similar to those used for other metals. Resin-bonded abrasives are preferred; sulfurized mineral-base oil and lard oil mixed with kerosene is used to flush the abrasive and to carry away heat. Table 12 lists honing specifications for aluminum alloys.

Honing is used to finish anodized aluminum surfaces (primarily the bores of some small aluminum engine blocks) and most aircraft hydraulic cylinders. Long anodized aluminum tubes (components of in-flight refueling apparatuses) are finished by manual honing. Tubes are chucked in a lathe, and the honing tool is moved manually. The oil supply is attached to the honing tool in such a manner that the flow of oil is directed where most needed. This method of honing is also used for finishing connecting-rod journals and crankshafts in aircraft overhaul shops.

Shot Peening

Shot peening is a method of cold working in which compressive stresses are induced in the exposed surface layers of metallic parts by the impingement of a stream of shot, which is directed at the metal surface at high velocity under controlled conditions. It differs from

Table 10 Applications for abrasive blast cleaning of aluminum products

Automatic rotary equipment with five nozzles was used for blasting all parts except the cake pan, for which a hand-operated single-nozzle setup was used.

Product	Size, mm	Size, in.	Abrasive Type	Abrasive Mesh size	Pieces, h
Blasting to prepare for organic coating					
Cake pan	280 by 380 by 50	11 by 15 by 2	Alumina	100	60
Frying pan	250 mm diam	10 in. diam	Alumina	100	260
Griddle	6775 mm^2	10.5 in.^{2}	Alumina	100	225
Sauté pan	200 mm diam	8 in. diam	Alumina	100	250
Blasting for appearance produced					
Army canteen(a)	...	...	Steel	80	420
Cocktail-shaker body(b)	100 mm diam by 180	4 in. diam by 7	Steel	80	375
Tray(b)	300 mm diam	12 in. diam	Steel	80	180

(a) 1-qt army canteen blasted for reduction of light reflectivity. (b) Blasted for decorative effect

Table 11 Conditions for wet blasting of aluminum-base materials

At a nozzle-to-work distance of 75 to 100 mm (3 to 4 in.) and an operating pressure of 550 kPa (80 psi)

Operation	Abrasive Type	Abrasive Mesh size
Deburr and clean	Alumina	220
Blend and grind	Silica flour	325
Lap and hone	Glass	1000

Table 12 Honing recommendations for aluminum alloys

Material	Hardness, HB (500 kg)	Honing stone material: Type	Honing stone material: Grade, ANSI or ISO	Grain size at a surface roughness, R_a, µm (µin.), of: 0.025–0.125 (1–5)	0.15–0.25 (6–10)	0.30–0.50 (11–20)	0.53–0.75 (21–30)	>0.75 (>30)	Spindle motion, m/min (ft/min): Rotating speed	Spindle motion: Reciprocating speed	Working pressure, kPa (psi)	Cutting fluid
Wrought and cast	30–450	Silicon carbide or diamond (metal bonded)	L(a)	600 (600)	500 (500)	400 (400)	280 (280)	220 (220)	15.2–64 (50–210)	2.7–22.9 (9–75)	276 (40)	70/30 kerosene/oil (sulfurized or chlorinated)

(a) L, a medium grade.

blast cleaning in primary purpose and in the extent to which it is controlled to yield accurate and reproducible results. Cast steel shot is the most widely used peening medium, but glass beads often are used for peening aluminum and other metals that might be contaminated by steel shot.

Although shot peening cleans the surface being peened, this function is incidental. The major purpose of shot peening is to increase fatigue strength. For example, the fatigue strength of several aluminum alloys peened with cast steel shot can be improved by 23 to 34%. The process has other useful applications, such as relieving tensile stresses that contribute to stress-corrosion cracking (SCC), and forming and straightening aluminum parts.

Peening action improves the distribution of stresses in surfaces that have been disturbed by grinding, machining, and heat treating. Shot peening is especially effective in reducing the harmful stress concentration effects of notches, fillets, forging pits, surface defects, and the heat-affected zones of weldments.

Surface tensile stresses that cause SCC can be effectively overcome by the compressive stresses induced by shot peening using either steel shot or glass beads. In one application, test bars were cut in the short transverse direction from an aluminum alloy 7075-T6 hand forging and stressed to 75% of the yield strength. During alternate immersion tests in 3.5% sodium-chloride solution, unpeened specimens failed in 1, 5, 17, and 28 days. Specimens peened in the unstressed condition with cast steel shot lasted 365 and 730 days, after which failure occurred in the unpeened grip outside the test area. During exposure to an industrial atmosphere, similar unpeened test bars failed in 20, 37, 120, and 161 days, whereas a peened specimen under the same conditions was uncracked when it was removed from testing after an exposure of 8.5 years.

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Metallurgy Basics for Aluminum Surface Treatment

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Aluminum, magnesium, titanium, and beryllium are classified as *light metals*, because whether used in their pure state or as alloys, their purpose is to reduce the weight of components and structures. The property of *lightness* is relative to the low density of the material, 2.7g/cm^3 and 1.7g/cm^3, for aluminum and magnesium respectively. Upon comparison to the density of other structural metals—7.9g/cm^3 for iron and 8.9g/cm^3 for copper—it is easy to see why light metals are the preferred materials in the transportation industry, especially in the aerospace and defense industries, where minimizing payload weight can reduce fuel consumption and decrease flight time, which are important economic considerations. (Ref 1)

Table 1 summarizes important properties of aluminum and the other light metals. (Ref 2) When compared to the other light metals, the moderate melting temperature of aluminum enables it to be processed at relatively low temperatures; yet the stability of aluminum over a broad temperature range enables its application in moderately high operating temperature conditions. Aluminum has high electrical and thermal conductivity; in fact, it is the best conductor in weight-to-weight comparison with copper. Aluminum has the capacity to efficiently reflect radiant energy, on which the use of aluminum foil is based. Aluminum is easy to machine, and the waste from processing is not toxic, like that from beryllium, or as reactive as magnesium. Because of the ease of extraction and processing, aluminum is not as expensive as titanium or carbon fiber composite materials.

Of the light metals, aluminum is the only one that has a face centered cubic (fcc) structure, which accounts for many of the unique characteristics of aluminum and aluminum alloys (Ref 3). The aluminum fcc crystal structure is without allotropes, which means it always stays fcc, in spite of remelting, deformation, and heat treatment. FCC structures have long interstitial sites, which accounts for easy alloying, ductility (highest % elongation for the light metals), ease of deformation along its many slip planes, and resistance to hydrogen embrittlement. Because aluminum has no allotropes, it can be recycled indefinitely without loss of properties. Recycling requires only 5% of the energy and produces only 5% of the CO_2 emissions as compared with primary production of aluminum from bauxite. This reduces the waste going to landfill, making aluminum the most cost-effective material to recycle (Ref 4). The ability to recycle indefinitely makes aluminum a truly sustainable engineering material—something to consider when comparing it with other light metals for design applications.

Table 1 Some important properties of the light metals

Property	Aluminum	Magnesium	Titanium	Beryllium
Color	White	Silvery-white	Silvery-white	Grayish
Density (kg/m^3)	2700	1740	4540	1850
Melting point, °C (°F)	660 (1220)	650 (1200)	1668 (3035)	1283 (2340)
Crystal structure	FCC	HCP	HCP, BCC(a)	HCP
Lattice parameter (nm)	0.405	a = 0.321 c = 0.521	a = 0.295 c = 0.468	a = 0.228 c = 0.358
Atomic (weight)	29.98	24.31	47.90	9.01
Tensile (strength), MPa (ksi)	72 (10)	78 (11)	400 (58)	325 (47)
Elongation (%)	60	2	27	≤ 8
Modulus of elasticity, GPa (ksi)	70 (10,000)	45 (6500)	116 (17,000)	303 (44,000)
Electrical conductivity (IACS)	64%	38%	4%	42%
Corrosion resistance	Very good	Good	Excellent	Moderate
Magnetic behavior	Nonmagnetic	Nonmagnetic	Nonmagnetic	Nonmagnetic
Specific feature(s)	Nontoxic, nonsparking	Readily oxidizes and burns	Readily oxidizes above 500 °C (930 °F)	Toxic, poor machinability

(a) Above 882 °C (1620 °F) with a = 0.331 nm Source: Ref 2

Pure aluminum derives its limited strength from atomic level defects such as dislocations and vacancies that are introduced to the fcc structure during solidification and deformation. These first-level defects increase the strength of pure aluminum by interrupting the long-range order of a perfect fcc crystal. Atomic-level structural and microstructural features, characteristic for all polycrystalline materials, change the chemical potential of the surface and therefore the corrosion resistance to external ions. Grains with varying crystallographic orientation also exhibit different electrochemical potentials, depending on the atomic packing density. In aluminum, the [111] plane is most reactive, because it has the highest packing density, followed by the [110] plane and the [100] plane (Ref 5), see Fig. 1. For aluminum, the presence of microstructural defects changes etch rates and oxide growth rates that correspond to grain orientation, which are manifested in processes such as cleaning, brightening, etching, conversion coatings, electroplating, and anodizing. Point defects such as vacancies and dislocations agglomerate and accumulate at grain boundaries, which change the interfacial energy and confound the electrochemical reaction at the surface, developing the microstructure on even the purest substrates (Ref 7).

The Aluminum Surface

The interface created with the surface and the corresponding environment (in the case of anodizing, with the electrolyte) is three-dimensional. Two-dimensional representations fall short of reality when considering surface