(14) Grinding Methods

Grinding, or abrasive machining, once performed on conventional milling machines, lathes and shapers, are now performed on various types of grinding machines.

Grinding machines have advanced in design, construction, rigidity and application far more in the last decade than any other standard machine tool in the manufacturing industry. Grinding machines fall into five categories: surface grinders, cylindrical grinders, centerless grinders, internal grinders and specials.

Surface grinding

Surface grinders are used to produce flat, angular and irregular surfaces. In the surface grinding process, the grinding wheel revolves on a spindle; and the workpiece, mounted on either a reciprocating or a rotary table, is brought into contact with the grinding wheel.

Four types of surface grinders are commonly used in industry: the horizontal spindle/reciprocating table; the horizontal spindle/rotary table; the vertical spindle/reciprocating table; and the vertical spindle/rotary table.

Horizontal spindle/reciprocating table — This surface grinder is the most commonly used type in machining operations. It is available in various sizes to accommodate large or small workpieces. With this type of surface grinder, the work moves back and forth under the grinding wheel. The grinding wheel is mounted on a horizontal spindle and cuts on its periphery as it contacts the workpiece.

Horizontal spindle/rotary table — This surface grinder also has a horizontally mounted grinding wheel that cuts on its periphery. The workpiece rotates 360 degrees on a rotary table underneath the wheelhead. The wheelhead moves across the workpiece to provide the necessary cross feed movements.

Vertical spindle/reciprocating table — This type is particularly suited for grinding long and narrow castings, like the bedways of an engine lathe. It removes metal with the face of the grinder wheel while the work reciprocates under the wheel. The wheelhead assembly, as on most other types of surface grinders, moves vertically to control the depth of cut. The table moving laterally accomplishes cross feed.

Vertical spindle/rotary table — This grinding machine is capable of heavy cuts and high metal-removal rates. Vertical spindle machines use cup, cylinder, or segmented wheels. Many are equipped with multiple spindles to successively rough, semi-finish, and finish large castings, forgings, and welded fabrications.

Workholding devices — Almost any workholding device used on a milling machine or drill press can be used on surface grinders. However, the most common workholding device on surface grinders is a magnetic chuck.

Cylindrical grinding

Cylindrical grinding is the process of grinding the outside surfaces of a cylinder. These surfaces may be straight, tapered or contoured. Cylindrical grinding operations resemble lathe-turning operations. They replace the lathe when the workpiece is hardened or when extreme accuracy and superior finish are required. As the workpiece revolves, the grinding wheel, rotating much faster in the opposite direction, is brought into contact with the part. The workpiece and table reciprocate while in contact with the grinding wheel to remove material.

Workholding devices — Workholding devices and accessories used on center-type cylindrical grinders are similar to those used on engine lathes.

Independent, universal and collet chucks can be used on cylindrical grinders when the work is odd-shaped or contains no center hole. These also are used for internal grinding operations.

Centerless grinding

Centerless grinding machines eliminate the need to have center holes for the work or to use workholding devices. In centerless grinding, the workpiece rests on a workrest blade and is backed up by a second wheel, called the regulating wheel. The rotation of the grinding wheel pushes the workpiece down on the workrest blade and against the regulating wheel. The regulating wheel, usually made of a rubber-bonded abrasive, rotates in the same direction as the grinding wheel and controls the longitudinal feed of the work when set at a slight angle. By changing this angle and the speed of the wheel, the workpiece feed rate can be changed.

Internal grinding

Internal grinders are used to finish straight, tapered or formed holes accurately. The most popular internal grinder is similar in operation to a boring operation in a lathe: The workpiece is held by a workholding device, usually a chuck or collet, and revolved by a motorized headstock. A separate motor head in the same direction as the workpiece revolves the grinding wheel. It can be fed in and out of the work and also adjusted for depth of cut.

Special grinding processes

Special types of grinders are grinding machines made for specific types of work and operations, for example:

Tool and cutter grinders. These grinding machines are designed to sharpen milling cutters, reamers, taps and other machine tool cutters. The general-purpose cutter grinder is the most popular and versatile tool-grinding machine. Various attachments are available for sharpening most types of cutting tools.

Jig grinding machines. Jig grinders were developed to locate and accurately grind tapered or straight holes. Jig grinders are equipped with a high-speed vertical spindle for holding and driving the grinding wheel. They utilize the same precision locating system as do jig borers.

Thread grinding machines. These are special grinders that resemble the cylindrical grinder. They must have a precision lead screw to produce the correct pitch, or lead, on a threaded part. Thread grinding machines also have a means of dressing or truing the cutting periphery of the grinding wheel so that it will produce a precise thread form on the part.

Creep-feed grinding

Traditionally, grinding has been associated with small rates of metal removal and fine finishing operations. However, grinding also can be used for large-scale metal-removal operations, similar to milling, broaching, and planning. In creep-feed grinding, developed in the late 1950s, the wheel depth of cut is as much as 0.25 in. and the workpiece speed is low.

Its overall competitive position with other material-removal processes indicates that creep-feed grinding can be economical for specific applications, such as in grinding shaped punches, twist-drill flutes, and various complex super alloy parts. The wheel is dressed to the shape of the workpiece to be produced. Although generally one pass is sufficient, a second pass may be necessary for improved surface finish.

Grinding wheel wear

The wear of a grinding wheel may be caused by three actions: attrition or wearing down, shattering of the grains, or breaking of the bond.

In most grinding processes, all three mechanisms are active to some extent. Attritions wear is not desirable because the dulled grains reduce the efficiency of the process, resulting in increased power consumption, higher surface temperatures, and surface damage. However, attrition must go on to some extent, with the forces on the grit being increased until they are high enough to shatter the grit or break the bond posts holding the dulled grit. The action of particles breaking away from the grains serves to keep the wheel sharp without excessive wear. However, the grains must eventually break from the bond or the wheel will have to be dressed. Rupturing the bond post that holds the grit allows dull grains to be sloughed off, exposing new sharp edges. If this occurs too readily, the wheel diameter wears down too fast. This raises wheel costs and prohibits close sizing on consecutive parts.

G-ratio — The G-ratio is the ratio of the amount of stock removed versus the amount of wear on the wheel, measured in cubic inches per minute. This ratio will vary from 1.0 to 5.0 in very rough grinding, and up to 25.0 to 50.0 in finish grinding.

Even though grinding wheels are fairly expensive a high G-ratio is not necessarily economical, as this may mean a slower rate of stock removal. It often takes some experimenting to find the wheel-metal combination, which is most economical for a job.

Attritions wear — Attritions wear is responsible for the so-called "glazed" wheel that occurs when flat areas are worn on the abrasive grains but the forces are not high enough to break the dull grains out of the wheel face. Attritions wear of the wheel occurs most often when fine cuts are taken on hard abrasive materials. Taking heavier cuts or using a softer wheel that will allow the grains to break out can often avoid it.

Grain fracture — The forces that cause the grain to shatter may arise from the cutting forces acting on the wheel, thermal conditions, shock loading, welding action between the grit and the chip, or combinations of these factors. In finish grinding, this type of wheel wear is desirable, because it keeps sharp edges exposed, and still results in a low rate of wheel wear. In time, the wheel may become 'loaded' and noisy, and require dressing.

A loaded wheel should be dressed by taking a few deep cuts with the diamond so that the metal-charged layer is removed, and the chips are not just pushed further into the wheel. Then, it should be finish-dressed according to the application requirements.

Bond fracture — It is desirable to have worn grit break out of the wheel so that new cutting edges will be exposed. This breaking down of the bond should progress fast enough so that heat generation is sufficiently low to avoid surface damage. On the other hand, bond breakdown should be slow enough so that wheel costs are not prohibitive. Normally, this means choosing the proper wheel grade for the job. Certain bond hardness is required to hold the grain in place. Softer wheels crumble too fast, while harder wheels hold the dull grit too long.

Coded abrasives

Typical examples of coated abrasives are sandpaper and emery cloth. The grains used in coated abrasives are more pointed than those used for grinding wheels. The grains are electro-statically deposited on flexible backing material, such as paper or cloth. The matrix or coating is made of resin.

Coated abrasives are available as sheets, belts and disks and usually have a much more open structure than the abrasives on grinding wheels. Coated abrasives are used extensively in finishing flat or curved surfaces of metallic or nonmetallic parts, and in woodworking. The surface finishes obtained depend primarily on the grain sizes.

Abrasive belt machining — Coated abrasives are also used as belts for high-rate material removal. Belt grinding has become an important production process, in some cases replacing conventional grinding operations such as the grinding of camshafts. Belt speeds are usually in the range of 2,500 to 6,000 ft/min. Machines for abrasive-belt operations require proper belt support and rigid construction to minimize vibration.

Grindability

Grindability, in a like manner as machinability, may be thought of as the ease with which material can be removed from the workpiece by the action of the grinding wheel. Surface finish, power consumption, and tool (wheel) life can be considered as fundamental criteria of the grindability of metals. In addition, there are the important factors of chip formation and susceptibility to damaging the workpiece. Chip formation, which leads to a ‘loaded’ wheel, is detrimental.

The most important machine setting affecting machinability, the cutting speed, is not as important an influence on grindability because grinding is done at more or less constant speed. Instead, the important factor becomes the nature of the grinding wheel. The type of grit, grit size, bond material, hardness and structure of the wheel all influence the grindability of the workpiece. The problems of tool material and configuration variables were discussed in connection with machinability.

In grinding operations like snagging and cut-off work, the surface finish, and even the metallurgical damage the workpiece, may become relatively unimportant. Wheel life and the rate of cut obtainable then become the criteria of grindability.

The best way to determine grindability is to start with the selection of the proper wheel. Beginning with the manufacturer's recommended grade for the conditions of the job and then trying wheels on each side of this grade will do this. Any improvement or deterioration in the grinding action, as evidenced by wheel wear, surface finish, or damage to the workpiece, can be noted. After the proper wheel has been chosen, wheel life data may be obtained. Usually, this can be done during the production run.

Some of the factors to consider in establishing grindability ratings are discussed in the following examples relative to the performance metals.

Cemented carbide material cannot be ground with aluminum-oxide grit wheels. Although it can be ground with pure silicon-carbide wheels, the grinding ratio is very low and the material is easily damaged. Carbide is easily ground with diamond wheels if light cuts are taken to prevent damage to the workpiece material. However, diamond-grit wheels are quite expensive, and the overall grindability of this material is very low.

High-speed steel can be ground quite successfully with aluminum-oxide grit wheels. The grinding ratio is low, the relative power consumption is high, and the possibility of damage to the workpiece is always present. Overall grindability is quite low.

Hardened steel (medium hard alloy or plain carbon steels) is easily ground with aluminum-oxide wheels. The grinding ratio is good, and damage to the workpiece is not a serious problem. The grindability rating is good.

Soft steels (annealed plain carbon steels) grind with relatively low power consumption. Aluminum-oxide wheels are satisfactory, and the grinding ratio is quite high, but surface damage may be encountered. As a group, these

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materials are rated as having good grindability.

Aluminum alloys (soft) grind with quite low power consumption, but they tend to load the wheel quickly. Wheels with a very oven structure are needed. Grinding ratios are good. Silicon-carbide grit works well, and belt grinding outperforms wheel grinding in many cases.