(9) Grinding Wheels and Operations

Grinding Wheels and Operations

Grinding or abrasive machining is the process of removing metal in the form of minute chips by the action of irregularly shaped abrasive particles. These particles may be in bonded wheels, coated belts, or simply loose.

Grinding wheels are composed of thousands of small abrasive grains held together by a bonding material. Each abrasive grain is a cutting edge. As the grain passes over the work piece it cuts a small chip, leaving a smooth, accurate surface. As each abrasive grain becomes dull, it breaks away from the bonding material.

Types of abrasives

Two types of abrasives are used in grinding wheels: manufactured and natural. Except for diamonds, manufactured abrasives have almost entirely replaced natural abrasive materials. Even natural diamonds have been replaced in some instances by synthetic diamonds.

The manufactured abrasives most commonly used in grinding wheels are Diamond,cubic Boron Nitride,Silicon Carbide and Aluminum Oxide.

Diamond: Two types of diamond are used in the production of grinding wheels: natural and manufactured. Natural diamond is a crystalline form of carbon, and very expensive. In the form of bonded wheels, natural diamonds are used for grinding very hard materials such as cemented carbides, marble, granite and stone.
Recent developments in the production of manufactured diamonds have brought their cost down and led to expanded use. Manufactured diamonds are now used for grinding tough and very hard steels, cemented carbide and aluminum oxide cutting tools.

Cubic boron nitride (CBN): Cubic boron nitride is an extremely hard, sharp and cool cutting abrasive. It is one of the newest manufactured abrasives and 2.5 times harder than aluminum oxide. It can withstand temperatures up to 2,500°F. CBN is produced by high-temperature, high-pressure processes similar to those used to produce manufactured diamond and is nearly as hard as diamond

Silicon carbide: Silicon carbide grinding wheels are made by mixing pure white quartz, petroleum coke and small amounts of sawdust and salt, and then by firing the mixture in an electric furnace. The process is called synthesizing the coke and sand. As in the making of aluminum oxide abrasive, the resulting crystalline mass is crushed and graded by particle size.

Silicon carbide wheels are harder and more brittle than aluminum oxide wheels. There are two principal types of silicon carbide wheels: black and green. Black wheels are used for grinding cast irons, non-ferrous metals like copper, brass, aluminum, and magnesium, and nonmetallics such as ceramics and gemstones. Green silicon carbide wheels are more friable than the black wheels and used for tool and cutter grinding of cemented carbide.

Aluminum oxide: Refining bauxite ore in an electric furnace makes aluminum oxide. The bauxite ore is heated to eliminate moisture, then mixed with coke and iron to form a furnace charge. The mixture is then fused and cooled. The fused mixture resembles a rocklike mass. It is washed, crushed and screened to separate the various grain sizes.

Aluminum oxide wheels are manufactured with abrasives of different degrees of purity to give them certain characteristics for different grinding operations and applications. The color and toughness of the wheel are influenced by the degree of purity.

General-purpose aluminum oxide wheels, usually gray and 95 percent pure are the most popular abrasives used. They are used for grinding most steels and other ferrous alloys. They are used for grinding most steels and other ferrous alloys. White aluminum oxide wheels are nearly pure and are very friable (able to break away from the material easily.) They are used for grinding high-strength, heat-sensitive steels.

Types of bonds

Abrasive grains are held together in a grinding wheel by a bonding material. The bonding material does not cut during grinding operation. Its main function is to hold the grains together with varying degrees of strength. Standard grinding wheel bonds are vitrified, resinoid, silicate, shellac, rubber and metal.

Vitrified bond: Vitrified bonds are used on more than 75 percent of all grinding wheels. Vitrified bond material is comprised of finely ground clay and fluxes with which the abrasive is thoroughly mixed. The mixture of bonding agent and abrasive in the form of a wheel is then heated to 2,400°F to fuse the materials.

Vitrified wheels are strong and rigid. They retain high strength at elevated temperatures and are practically unaffected by water, oils or acids. One disadvantage is that they exhibit poor shock resistance. Therefore, their application is limited where impact and large temperature differentials occur.

Resinoid bond: Resinoid bonded grinding wheels are second in popularity to vitrified wheels. Phenolic resin in powdered or liquid form is mixed with the abrasive grains in a form and cured at about 360F. Resinoid wheels are used for grinding speeds up to 16,500 SFPM. Their main use is in rough grinding and cut-off operations.

Silicate bond: This bonding material is used when heat generated by grinding must be kept to a minimum. Silicate bonding material releases the abrasive grains more readily than other types of bonding agents. Speed is limited to below 4,500 SFPM.

Shellac bond: It's an organic bond used for grinding wheels that produce very smooth finishes on parts such as rolls, cutlery, camshafts and crankpins. Generally, they are not used on heavy-duty grinding operations.

Rubber bond: Rubber-bonded wheels are extremely tough and strong. Their principal uses are as thin cut-off wheels and driving wheels in centerless grinding machines. They are used also when extremely fine finishes are required on bearing surfaces.

Metal bond: Metal bonds are used primarily as binding agents for diamond abrasives. They are also used in electrolytic grinding where the bond must be electrically conductive.

Abrasive grain size

The size of an abrasive grain is important because it influences stock removal rate, chip clearance in the wheel and surface finish obtained.

Abrasive grain size is determined by the size of the screen opening through which the abrasive grits pass. The number of the nominal size indicates the number of the openings per inch in the screen. For example, a 60-grit-sized grain will pass through a screen with 55 openings per inch, but it will not pass through a screen size of 65. A low grain size number indicates large grit, and a high number indicates a small grain.

Grain sizes are broadly defined as coarse (6 to 24), medium (30 to 60), fine (70 to 180), and very fine (220 to 1,000.) Very fine grits are used for polishing and lapping operations, fine grains for fine-finish and small-diameter grinding operations. Medium grain sizes are used in high stock removal operations where some control of surface finish is required. Coarse grain sizes are used for billet conditioning and snagging operations in steel mills and foundries, where stock removal rates are important and there is little concern about surface finish.

Grinding wheel grade

The grade of a grinding wheel is a measure of the strength of the bonding material holding the individual grains in the wheel. It is used to indicate the relative hardness of a grinding wheel. Grade or hardness refers to the amount of bonding material used in the wheel, not to the hardness of the abrasive.

The range used to indicate grade is A to Z, with A representing maximum softness and Z maximum hardness. The selection of the proper grade of wheel is very important. Wheels that are too soft tend to release grains too rapidly and wheel wear is great. Wheels that are too hard do not release the abrasive grains fast enough and the dull grains remain bonded to the wheel causing a condition known as "glazing."

Grinding wheel structure

The structure of a grinding wheel refers to the relative spacing of the abrasive grains; it is the wheel's density. There are fewer abrasive grains in an open-structure wheel than in a closed-structure wheel. A number from 1 to 15 designates the structure of a wheel. The higher the number, the more open the structure will be; and the lower the number, the more dense the structure will be.

Grinding wheel specifications

Grinding wheel manufacturers have agreed to a standardization system to describe wheel composition as well as wheel shapes and faces.

Grinding wheel markings

Abrasive grinding wheels have a different marking system than CBN and diamond wheels.

Abrasive grinding wheels: This marking system is used to describe the wheel composition as to type of abrasive, grain size, grade, structure and bond type.

CBN and diamond wheels: The same standardization is applicable to CBN and diamond wheels. Wheel markings are a combination of letters and numbers.

Grinding wheel shapes and faces

Most grinding wheel manufacturers have adopted eight standard wheel shapes and 12 standard wheel faces for general use. The illustration shows the most common standard wheel shapes used on all types of grinders. A following illustration shows the standard wheel faces used on most grinding wheel shapes.

Electroplated grinding wheels

Of the several methods now used for fixing super abrasive particles of diamond or CBN to the working surface of an abrasive tool, electroplating is the fastest growing. More and more production operations involve combinations of hard-to-grind materials and complex wheel shapes that virtually dictate the use of electroplated super-abrasive tools.

Characteristically, such tools consist of a precision tool form or mandrel with super-abrasive particles deposited on the working surface and locked in place by electrodeposition of a bonding matrix, most frequently nickel. The particles are so locked onto the tool surface may vary in size and dispersion to suit the purpose of the tool, but they should lie in a single layer.

Wheel Balancing, dressing and truing

All grinding wheels are breakable, and some are extremely fragile. Great care should be taken in handling grinding wheels. New wheels should be closely inspected immediately after receipt to make sure they were not damaged during transit. Grinding wheels should also be inspected prior to being mounted on a machine.

To test for damage, suspend the wheel with a finger and gently tap the side with a screwdriver handle for small wheels, and a wooden mallet for larger wheels. An undamaged wheel will produce a clear ringing sound; a cracked wheel will not ring at all.

Wheel balancing

It is important to balance wheels over 10 inches before they are mounted on a machine. The larger the grinding wheel, the more critical balancing becomes. Balance also becomes more critical as speed is increased. Out-of-balance wheels cause excessive vibration, produce faster wheel wear, chatter, poor finishes, damage to spindle bearings, and can be dangerous.

The proper procedure for balancing wheels is to first statically balance the wheel. Next, mount the wheel on the grinding machine and dress. Then remove the wheel and rebalance it. Remount the wheel and dress slightly a second time.

Shifting weights on the wheel mount will balance the wheels. The wheel is installed on a balancing arbor and placed on a balancing fixture. Then, the weights are shifted in a position to remove all heavy points on the wheel assembly.

Wheel dressing and truing

Dressing is a process used to clean and restore a dulled or loaded grinding wheel-cutting surface to its original sharpness. In dressing, swarf is removed, as well as dulled abrasive grains and excess bonding material. In addition, dressing is used to customize a wheel face so that it will give desired grinding results.

Truing is the process of removing material from the face of the wheel so that the resultant cutting surface runs absolutely true. This is very important in precision grinding because an out-of-true wheel will produce objectionable chatter marks on the work piece. A new wheel should always be trued before being put to work. Also, it is a good idea to true the wheel if it's being remounted on a machine.

Dressing and truing conventional grinding wheels are two separate and distinct operations, although they may sometimes be done with the same tool. The tools used for conventional grinding wheel dressing include:

Mechanical dressers, commonly called star dressers, are held against the wheel while it is running. The picking action of the points of the star-shaped wheels in the tool remove dull grains, bond, and other bits of swarf. Star dressers are used for relatively coarse-grained conventional wheels, generally in off-hand grinding jobs where grinding accuracy is not the main consideration.

Dressing sticks are used for off-hand dressing of smaller conventional wheels, especially cup and saucer shapes. Some of these sticks are made of an extremely hard abrasive called boron carbide. In use, a boron carbide stick is held against the wheel face to sear the dull abrasive grains and remove excess bond. Other stressing sticks contain coarse Crystolon or Alundum grains in a hard vitrified bond.

Diamond dressing tools utilize the unsurpassed hardness of a diamond point to clean and restore the wheel grinding face. Although single-point diamond tools were once the only products available for this kind of dressing, the increasing scarcity of diamonds has led to the development of multi-point diamond tools.

Multi-point diamond dressing tools use a number of small diamonds held in a matrix. In use, the tool is held securely in the tool holder and held flat against the face of the running wheel. As it dresses, the tool is traversed across the wheel face until the job is done. As diamonds on the surface of the tool wear away, fresh new diamond points are exposed to offer extended life and use. This type of tool produces a very consistent wheel face from dress to dress.

Multi-point diamond dressing tools are available in a wide range of shank diameters and face shapes to meet the requirements of a broad variety of grinding machines.
Grinding wheel selection

Before attempting to select a grinding wheel for a particular operation, the operator should consider the following six factors for maximum productivity and safe results:

Material to be ground: If the material to be ground is carbon steel or alloy steel, aluminum oxide wheels are usually selected. Extremely hard steels and exotic alloys should be ground with cubic boron nitride (CBN) or diamond. Nonferrous metals, most cast irons, nonmetallics, and cemented carbides require a silicon carbide wheel. A general rule on grain size is to use a fine grain wheel for hard materials, and a coarse grain wheel for soft and ductile materials.

Nature of the grinding operation: Finish required, accuracy and amount of metal to be removed must be considered when selecting a wheel. Fine and accurate finishes are best obtained with small grain size and grinding wheels with resinoid, rubber or shellac bonds.

Area of contact: The area of contact between the wheel and work piece is also important. Close-grain spacing, hard wheels and small-grain sizes are used when the area of contact is small.

Condition of the machine: Vibration influences the finish obtained on the part as well as wheel performance.

Grinding wheel speed: Wheel speed affects the bond and grade selected for a given wheel. Wheel speeds are measured in surface feet per minute (SFPM). Vitrified bonds are commonly used to 6,500 SFPM or in selected operations up to 12,000 SFPM. Resinoid-bonded wheels may be used for speeds up to 16,500 SFPM.

Grinding pressure: Grinding pressure is the rate of in-feed used during a grinding operation; it affects the grade of wheel. A general rule to follow is that as grinding pressures increase harder wheels must be used.

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