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1. Grinding

To grind means to abrade, to wear away by friction, or to sharpen. In manufacturing it refers to the removal of metal by a rotating abrasive wheel. Wheel action is similar to a milling cutter. The cutting wheel is composed of many small grains bonded together, each one acting as a miniature cutting point(1).

1.1. Types of grinders

Cylindrical grinders

This machine is used primarily for grinding cylindrical surfaces, although tapered and simple format surfaces may also be ground. They may be further classified according to the method of supporting the work. Diagrams illustrating the essential difference in supporting the work between centers and centerless grinding are shown in figure 23.2. In the centerless type the work is supported by the work rest the regulating wheel, and the grinding wheel itself. Both types use plain grinding wheels with the grinding face as the outside diameter.

![Fig. plain cylindrical grinder](image)

The depth of cut is controlled by feeding the wheel into the work. Roughing cuts around 0.002 in(0.05 mm) per pass may be made but for finishing this should be reduced to about 0.0002 in (0.005 mm) per pass or less. In selecting the amount of in feed, consideration is given to the size and rigidity of the work, surface finish and the decision of whether or not to use a coolant.

Where the face of the wheel is wider than the part to be ground it is not necessary to traverse the work. This is known as plunge cut grinding. The grinding speed of the wheel is terms of surface feet per minute that is,

\[ V_c = \pi D_c x N \]

Where

- \( V_c \) = Cutting or grinding speed(m/min)
- \( D_c \) = Diameter of grinding wheel(m)
N=Revolutions of the wheel per minute (rpm)

Centerless grinders

Centerless grinders are designed so that they support and feed the the work by using two wheels and a work rest as illustrated in figures 23.2 and 23.4. The large wheel is the grinding wheel and the smaller one the pressure or regulating wheel. The regulating wheel is a rubber-bonded abrasive having the frictional characteristics to rotate the work at its own rotational speed. The speed of this wheel, which may be controlled, varies from 50 to 200 ft/min (0.25-1.02 m/s). Both wheels are rotating the same direction. The rest assists in supporting the work while it is being ground, being extended on both sides to direct the work travel to and from the wheels.

The axial movement of the work past the grinding wheel is obtained by tilting the wheel at a slight angle from horizontal. An angular adjustment of 0° to 10° is provided in the machine for this purpose. The actual feed can be calculated by this formula (1).

\[ F = \pi d N \sin \alpha \]

F=Feed (mm/min)
N=rpms
d=Diameter of regulating wheel (mm)
\( \alpha \)=Angle inclination of regulating wheel

Fig. Centerless grinding of ball bearings

Internal grinders
The work done on an internal grinder is diagrammatically shown in 23.6 tapered holes or those having more than one diameter may be accurately finished in this manner. There are several types of internal grinders.

![Centerless internal grinding](image1)

**Fig. Centerless internal grinding**

**Surface grinding**

Grinding flat or plane surfaces is known as surfaces grinding. Two general types of machines have been developed for this purpose; those of the planer type with a reciprocating table and those having a rotating worktable. Each machine has the possible variation of a horizontal or vertical positioned grinding wheel spindle. The four possibilities of construction are illustrated below figure.

![Types of surface grinding machines](image2)

**Fig. Types of surface grinding machines**

**Tool and cutter grinder**

In grinding tools by hand a bench or pedestal type of grinder is used. The tool is hand held and moved across the face of the wheel continually to avoid excessive grinding in one spot. For sharpening miscellaneous cutters a universal type grinder is used.

**2. Types of Grinding wheels**
Fig. Grinding wheel

A **grinding wheel** is an expendable wheel that carries an abrasive compound on its periphery. These wheels are used in grinding machines.

The wheel is generally made from a matrix of coarse particles pressed and bonded together to form a solid, circular shape, various profiles and cross sections are available depending on the intended usage for the wheel. They may also be made from a solid steel or aluminium disc with particles bonded to the surface.

Materials used are generally silicon carbide and diamond with a vitrified bonding agent. In production grinding, a wide array of materials are used. Wheels with different abrasives, structure, bond, grade, and grain sizes are available. The abrasive is the actual cutting material, such as cubic boron nitride, zirconia aluminum oxide, manufactured diamonds, ceramic aluminum oxide, aluminum oxide, and others. The abrasive is selected based on the hardness of the material being cut. The structure of the wheel refers to the density of the wheel (bond and abrasive versus airspace). A less-dense wheel will cut freely, and has a large effect on surface finish. A less dense wheel is able to take a deeper or wider cut with less coolant, as the chip clearance on the wheel is greater. The grade of the wheel determines how tightly the bond holds the abrasive. Grade affects almost all considerations of grinding, such as wheel speed, coolant flow, maximum and minimum feed rates, and grinding depth. Grain size determines the physical abrasive size in the wheel. A larger grain will cut freely, allowing fast cutting but poor surface finish. Ultra-fine grain sizes are for precision finish work, where a fine surface finish is required. The wheel bonding agent determines how the wheel holds the abrasives. This affects finish, coolant, and minimum/maximum wheel speed.

The manufacture of these wheels is a precise and tightly controlled process, due not only to the inherent safety risks of a spinning disc, but also the composition and uniformity required to prevent that disc from exploding due to the high stresses produced on rotation.

Grinding wheels are self sharpening to a small degree, for optimal use they may be dressed and trued by the use of grinding dressers. **Dressing** the wheel refers to removing the current layer of abrasive, so that a fresh and sharp surface is exposed to the work surface. **Truing** the wheel makes the grinding surface parallel to the grinding table or other reference plane, so the entire grinding wheel is even and produces an accurate surface.

The wheel type (eg:- cup or plain wheel below) fit freely on their supporting arbors, the necessary clamping force to transfer the rotary motion being applied to the
wheels side by identically sized flanges (metal discs). The paper blotter shown in the images is intended to distribute this clamping force evenly across the wheels surface.

2.1. Cup wheel

Fig. Cup wheel

A **cup wheel** as pictured to the right is predominantly used in Tool and Cutter grinders where orientation of the wheel and a slim profile are required. These wheels are used (and dressed) on the side face and have the advantage of producing a truly flat surface on the side of lathe tools. They are used in jig grinders to produce flat surfaces or counterbores.

2.2. Straight wheel

Fig. Straight wheel

To the left is an image of a **straight wheel**. These are by far the most common style of wheel and can be found on bench or pedestal grinders. They are used on the periphery only and therefore produce a slightly concave surface (*hollow ground*) on the part. This can be used to advantage on many tools such as chisels.

2.3. Cylinder wheel

Cylinder wheels provide a long, wide surface with no center mounting support (hollow). They can be very large, up to 12” in width. They are used only in vertical or horizontal spindle grinders.

2.4. Tapered wheel

A straight wheel that tapers outward towards the center of the wheel. This arrangement is stronger than straight wheels and can accept higher lateral loads.

2.5. Straight cup
Straight cup wheels are an alternative to cup wheels in tool and cutter grinders, where having an additional radial grinding surface is beneficial.

2.6. Dish cup

A very shallow cup-style grinding wheel. The thinness allows grinding in slots and crevaces. It is used primarily in cutter grinding and jig grinding.

2.7. Saucer wheel

A special grinding profile that is used to grind milling cutters and twist drills. It is most common in non-machining areas, as sawfilers use saucer wheels in the maintenance of sawblades.

2.8. Diamond wheel

![Diamond Wheel](image)

Diamond wheels are grinding wheels with industrial diamonds bonded to the periphery.

They are used for grinding extremely hard materials such as carbide tips, gemstones or concrete. The saw pictured to the right is a slitting saw and is designed for slicing hard materials, typically gemstones.

2.9. Diamond Mandrels

Diamond mandrels are very similar to their counterpart, a diamond wheel. They are tiny diamond rasps for use in a jig grinder doing profiling work in hard material.

3. Cut off wheels

Cut off or parting wheels are self-sharpening wheels that are thin in width and often have radial fibres reinforcing them. They are often used in the construction industry for cutting reinforcement steel (rebar), protruding bolts or anything that needs quick removal or trimming. Most handymen would recognise an angle grinder and the discs they use.

4. Grinding wheel flanges clamping force

The clamping force of the grinding wheel flanges is an important safety parameter of a grinding operation:
- it must be high enough to drive the wheel without slippage under the most severe operating conditions of the machine.

- it must not apply to the wheel an excessive compression stress which could weaken the wheel.

- it must not distort the flanges.

5. References

3. El – Hoffy : Advance Machining Process, Mc Graw Hill Companies, 0.007-1466940, 2005