

INTRODUCTION

Grinding is a metal cutting operation performed by abrasive particles mounted rigidly on a rotating wheel. Each of the abrasive particles acts as a single-point cutting tool and the wheel acts as a multi-point cutting tool. The grinding operation is used to finish the pieces with an extremely high-quality finish and accuracy of shape and size. Grinding is one of the widely accepted finishing operations because it removes the material into a very small chip size from 0.25 to 0.50 mm. Provides an accuracy of the order of 0.000025 mm. It is also possible to grind very hard material.

Objectives

After studying this unit, you should be able to

- provide excellent quality of surface finish to the surface,
- impart high quality of accuracy of shape and dimension,
- finishing of hardened metallic surfaces,
- sharpening of cutting edges of cutting tools,
- maintaining tool geometry of cutting tools,
- flattening and forming of surfaces,
- finishing of castings by removing impressions of sprues, risers, parting lines, etc., and
- Removal of scales and burrs, etc.

TYPES OF GRINDING

There can be different criteria to classify grinding into different categories. On the basis of quality of grinding, it is classified as rough grinding and precision grinding.

Rough Grinding

It involves removal of stock without any reference to the accuracy of results. Generally, rough grinding is followed by precision grinding.

Precision Grinding

Precision grinding removes an insignificant amount of metal. It is used to produce finished parts and precise dimensions.

Depending on the geometry of the work piece and the position in which the workpiece is to be crushed, it can be classified as external grinding, internal grinding, surface grinding, grinding adjustment and lower center grinding. Each of the above categories can be further classified, which will be explained below.

Based on the mounting position of a grinder it can be classified as a standing grinder (which can be installed on the ground); bench grinder, manual grinder, etc.

Depending on the spindle position, it can be classified as a horizontal spindle environment in which the grinding operation is performed; The grinding operation is classified as dry grinding and wet grinding. When the cutting fluid is distributed on the workpiece, the face and the sides of the wheel, it is called wet grinding. The commonly used cutting fluid is soda water. The temperature of the grinding zone reaches up to 2000 ° C in case of grinding of hard materials. The use of cutting fluid reduces the temperature and thus promotes the useful life of the wheel. However, in the case of dry grinding, refrigerant is not used. It is generally used when the material of the piece is not very hard and also the grinding time is reduced. Normally, dry grinding produces two undesirable effects of discoloration and smudging which are eliminated in the case of wet grinding. Some of the grinding machines are identified on the basis of their specific uses. Such grinders are

called special purpose grinders like crank shaft grinders; piston grinder; roll grinders; cam grinders; thread grinders; way grinders and tool post grinders. These are nomenclature on the basis of their specific uses.

SHAPES AND SIZE OF A GRINDING WHEEL

The abrasive wheels are manufactured in different shapes and sizes to adapt them to different types of grinders and in different types of work. These are classified into some groups based on their shapes and sizes. The shapes of the wheels are standardized so that those commonly used in production and in the tool room can be indicated by a number or name, or both. Some of the standard abrasive wheels are shown below. These are generally used for cylindrical, internal, center and smaller surface grinding operations. These wheels vary in size, diameter and width of the face. All parameters depend on the working clays for which the wheel is used, the size and the power of the sander used by the wheel.

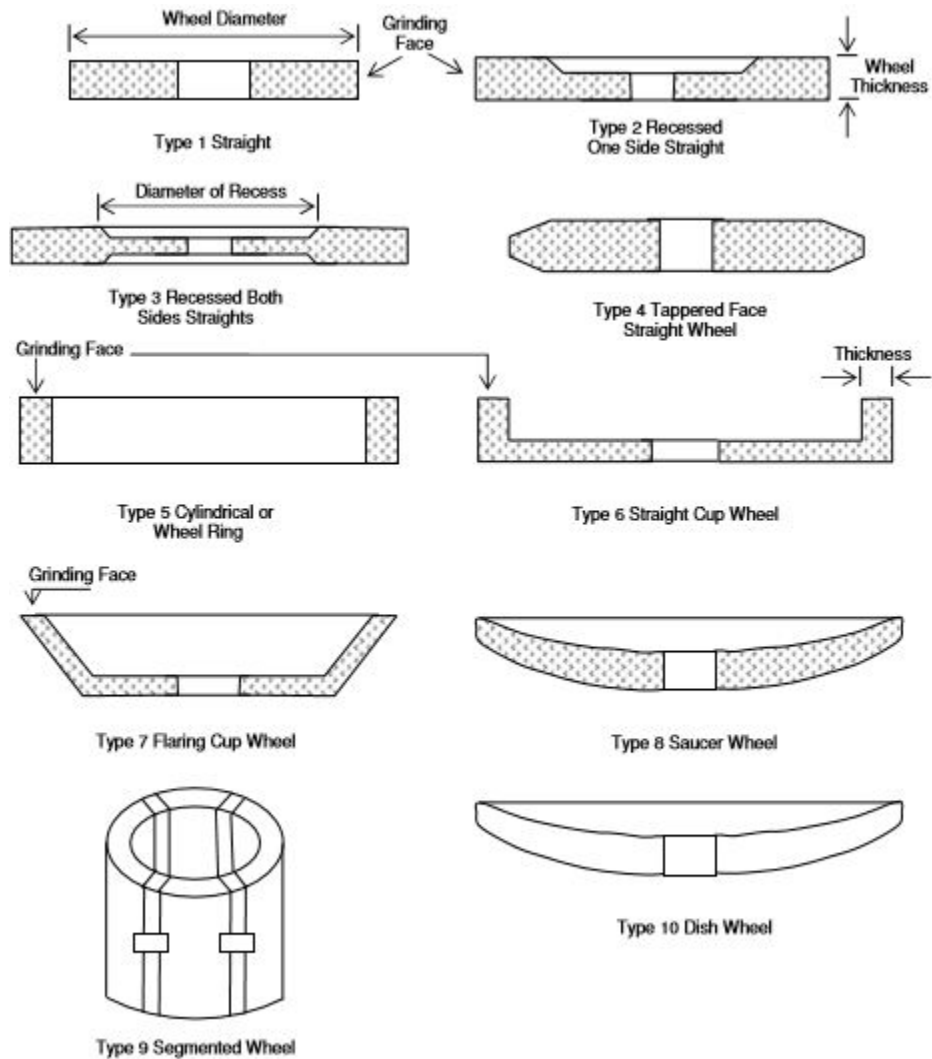


Fig.1

Tapered Face Straight Wheels

This is Type 4 in Figure. 1. It is also a straight wheel but its free is slightly tapered to facilitate the grinding of threads a gear tooth.

Cylindrical Wheel Ring

Cylindrical grinding wheel is shown in Figure 1 Type 5. It is used for surface grinding, i.e. production of flat surfaces. Grinding takes place with the help of face of the wheel.

Cup Wheel

Cup wheel shown in Figure 1 Type 6. It is used for grinding flat surfaces with the help of face of grinding wheel.

Flaring Cup Wheel

One modified grinding wheel named as flaring cup wheel is Type 7 in Figure 1. It is used in grinding of tools in tool room.

Wheel Diameter Grinding Face

Wheel Thickness

Type 1 Straight

Type 2 Recessed One Side Straight

Diameter of Recess

Type 3 Recessed Both Sides Straights

Type 4 Tapered Face Straight Wheel Grinding Face Thickness

Type 5 Cylindrical or Wheel Ring

Type 6 Straight Cup Wheel

Grinding Face

Type 7 Flaring Cup Wheel

Type 8 Saucer Wheel

Type 10 Dish Wheel

Type 9 Segmented Wheel

Saucer Wheel

Saucer wheel shown in Figure 1 at type 8. It is used for sharpening of circular or band saw.

Segmented Wheel

Segmented wheel shown in Figure 1 at Type 9. These are normally on vertical spindle, rotary type and reciprocating type surface grinders.

Dish heel

Dish wheel shown in Figure 1 Type 10. It is also used for grinding of tools in tool room. It is capable to grind very narrow places due to its thinners.

Size of a Grinding Wheel

Major dimensions of a grinding wheel are the outside diameter; bore diameter; and width of the face. In addition to the above geometry of the face of grinding wheel also matters. It may be flat, pointed, concave, convex, etc.

Coding of a Grinding Wheel

The Indian Standard Coding system of grinding wheel is IS: 551-195 it provides uniform system of coding of grinding wheels to designate their various characteristics. It gives a general indication of the hardness and grit size of any wheel as compared with another. Coding of a grinding wheel consists of six symbols as described below.

- W: Symbol for Manufacturer's Abrasive Type (Prefixed)
- C: Name of Abrasive
- 30: Grain Size
- L: Grade
- 5: Structure Type
- R: Bond Type

Manufacturer Symbol for Record (Suffix)

The sequence of codes of a grinding should be followed in the same sequence as described above. There are six symbols and first one which is seventh, is optional. Their brief description is given below.

Manufacturer's Symbol

It is optional symbol and criteria of its assignment entirely depend on the manufacturer's choice.

Abrasive Type

This is a alphabet symbol used to indicate the name of abrasive used 'A' stands for Aluminum Oxide and 'C' stands for Silicon Carbide.

Grain Size

This number provides idea of grain size of abrasives. It is also called grit. This number is decided on the basis of number of holes in one-inch length of the sieve used to filter the abrasive particles. Larger number indicates finer grain sizes. On the basis of grain size abrasive particles can be categorized in four categories as given below.

Class Grain Size of Abrasive (Grit)					
Coarse	10	12	14	16	20
Medium	30	36	46	54	60
Fine	80	100	120	150	180
Very fine	220	240	280	320	400

Grain size depends upon quantity of material to be ground required quality of surface finish; and hardness of work piece material. Fine and very fine grain size is used for precision grinding, however, coarse and medium grain size is used for rough grinding.

Grade

Grade of a grinding wheel is the indicative of hardness and tenacity of bond of abrasives. It is represented by capital letters of alphabet 'A' to 'Z' as described below.

Class	Coding for Grade							
Soft	A	B	C	D	E	F	G	H
Medium	I	J	K	L	M	N	O	P
Hard	Q	R	S	T	U	V	W	X

The choice of grade depends on the hardness of the workpiece material, on the grinding speed, on the contact area of the grinding wheel with the work piece, on the capacity of the grinding machine. Abrasive wheels are called soft, rigid or hard wheels depending on their grade. Abrasive wheel abrasives break quickly, so they are recommended for grinding the work piece of low hardness and soft and abrasive wheels are recommended for work pieces of hard material.

Structure of a Grinding Wheel

It includes number of abrasives and number of pores in unit volume. The distribution of abrasives and bores decides the structure of a grinding wheel. On the basis of structure grinding wheels are called dense or open grinding wheel. In case of dense grinding wheels abrasive particles are densely packed as compared to open grinding wheel with larger porosity. Generally, structure of grinding wheel is coded in number. Higher number indicates open structure of grinding wheel. Structure codes are given below.

Structure Code

Dense structure	1	2	3	4	5	6	7	8
Open structure	9	10	11	12	13	14	15	

Selection of an appropriate structure depends on hardness of work piece material; required quality of surface finish; and type of grinding operation. Normally open structure wheels are recommended for rough grinding and for softer materials. Dense structured grinding wheels are recommended for hard and brittle materials.

Type of Bond

Bond is the binding of abrasive particles together with the help of adhesive substance. Different types of bond will be discussed later. Selection of a bond depends on the type of grinding operation; work piece material, required bond strength and contact area of work piece with the grinding wheel.

Manufacturer's Symbol

Two-digit numbers are used for this symbol. This is to be defined and followed by the manufacturer for his own record.

VARIOUS ELEMENTS OF GRINDING WHEEL

Grinding wheel is a multipoint cutting tool having abrasive particles bonded together and so forming a structure. The various main elements of a grinding wheel are abrasive; bonds and structure which are described below. Abrasives

Generally abrasive properties like hardness, toughness and resistance to fracture uniformly abrasives are classified into two principal groups:

- (a) Natural abrasives, and
- (b) Artificial abrasives.

Natural Abrasives There are a few examples of natural abrasives which include sand stone (solid quartz); emery; corundum and diamond. Diamond is not recommended to use as abrasive due to its cost in effectiveness. However, diamond dust which is the waste of diamond dressing operation can be used as abrasives. Natural abrasive are being described below.

Sand stone is one of the natural abrasive used to make grinding stones. These are relatively soft. These cannot be used for grinding of hard material and at faster speed. Emery is a natural aluminum oxide containing 55 to 65% alumina, rest are iron oxide and impurities. If percentage of aluminum oxide is more, ranging from 75 to 95% then it is called corundum. It consists impurities as remaining amount. Both emery and corundum are harder than quartz and can have better abrasive action. Normally natural abrasives are not preferred due to presence of larger impurities and lack of uniformly in constituents.

Artificial Abrasives

Main artificial abrasive are silicon carbide and aluminum oxide. Artificial abrasive is preferred in manufacturing of grinding wheels because of their uniformity and purity. Artificial abrasives are described below.

Silicon Carbide

It is also called carbonado, It is manufactured from 56 parts of silica sand, 34 parts of powdered cake, 2 parts of salt, 12 parts of saw dust in a long rectangular electric furnace of resistance type. Sand furnishes silicon, cake furnishes carbon, and saw dust makes the charge porous, salt helps in fusing it. There are two types of silicon carbide abrasive, green grit with approximately 97% silicon carbide and black grit with approximately 95% silicon carbide. It is less hard than diamond and less tough than aluminum oxide. It is used for grinding of material of low tensile strength like cemented carbide, stone and ceramic, gray cast iron, brass, bronze, aluminum vulcanized rubber, etc.

Aluminum Oxide

It is prepared by heating mineral bauxite, a hydrated aluminum oxide clay containing silica, iron oxide, titanium oxide mixed with ground coke and iron borings in a arc type electric furnace. Aluminum oxide is tough and fracture resistant. It is preferred for grinding of materials of higher tensile strengths like steel; high carbon and high speed steel and tough bronze.

Bonds

A bond is an adhesive material used to held abrasive particles together; relatively stable that constitutes a grinding wheel. Different types of bonds are:

- (a) Vitrified bond,
- (b) Silicate bond, Grinding
- (c) Shellac bond,
- (d) Resinoid bond,
- (e) Rubber bond, and

(f) Oxychloride bond.

These bonds are being explained here in brief.

Vitrified Bond

This bond consists of mixture of clay and water. Clay and abrasives are thoroughly mixed with water to make a uniform mixture. The mixture is molded to shape of a grinding wheel and dried up to take it out from mould. Perfectly shaped wheel is heated in a kiln just like brick making. In this way clay vitrifies and fuses to form a porcelain or glass grains. High temperature also does annealing of abrasive. This wheel possesses a good strength and porosity to allow high stock removal with coal cutting. Disadvantage of this type of wheel are, it is sensitive for heat, water, oil and acids. Their impact and bending strengths are also low. This bond is denoted by symbol 'V' in specification.

Silicate Bond

Silicate bonds are made by mixing abrasive particles with silicate and soda or water glass. It is molded to required shape, allowed to dried up and then taken out of mould. The raw molded wheel is baked in a furnace at more than 200oC for several days. These wheel exhibits water proofing properly so these can be used with coolant. These wheels are denoted by 'S' in specification.

Shellac Bond

These are prepared by mixing abrasive with shellac than molded by rolling and pressing and then by heating up to 150oC for several hours. This bond exhibits greater elasticity than other bonds with appreciable strength. Grinding wheels having shellac bond are recommended for cool cutting on hardened steel and thin sections, finishing of chilled iron, cast iron, steel rolls, hardened steel cams and aluminum pistons. This bond is denoted by 'E' in specifications.

Resinoid Bond

These bonds are prepared by mixing abrasives with synthetic resins like backelite and redmanol and other compounds. Mixture is molded to required shape and baked up to 200oC to give a perfect grinding wheel. These wheels have good grinding capacity at higher speed. These are used for precision grinding of cams, rolls and other objects where high precision of surface and dimension influence the performance of operation. A resinoid bond is denoted by the letter 'B'.

Rubber Bond

Rubber bonded wheels are made by mixing abrasives with pure rubber and sulphur. After that the mixture is rolled into sheet and wheels are prepared by punching using die and punch. The wheels are vulcanized by heating then in furnace for short time. Rubber bonded wheels are more resilient and have larger abrasive density. These are used for precision grinding and good surface finish. Rubber bond is also preferred for making thin wheels with good strength and toughness. The associated disadvantage with rubber bond is, these are lesser heat resistant. A rubber wheel bonded wheel is denoted by the letter 'R'.

Oxychloride Bond

These bonds are processed by mixing abrasives with oxides and chlorides of magnesium. The mixture is molded and baked in a furnace to give shape of a grinding wheel. These grinding wheels are used for disc grinding operations. An ox chloride bonded wheel is specified the letter 'O'.

PARAMETERS OF GRINDING OPERATION

Normal parameters used in grinding operation are cutting speed, feed rate and depth of cut. These parameters are described below.

Cutting Speed

Cutting speed is grinding wheel is the relative peripheral speed of the wheel with respect to the work piece. It is expressed in meter per minute or meter per second. The cutting speed of grinding wheel can be calculated as

$$\text{mpm (meter per minute)} \quad 1000 \pi = D N V$$

where, D is diameter of grinding wheel in mm. N are the number of revolution of grinding wheel if N is expressed in number of revolutions per minute, V will be in mpm, if N is expressed in number of revolution per second, V will be in mps.

Feed Rate

Feed rate is a significant parameter in case of cylindrical grinding and surface grinding. Feed rate is defined as longitudinal movement of the work piece relative to axis of grinding wheel per revolution of grinding wheel. Maximum feed rate should be up to 0.9 time of face width of grinding wheel for rough grinding and up to 0.6 times of face width of grinding wheel for finish grinding. Feed cannot be equal to or more than the width of grinding wheel. Feed is used to calculate the total grinding time as given below.

$$T = (L i / S N) \times K$$

Where T is the grinding time (min) L is the required longitudinal travel in mm. i is the number of passes required to cover whole width S is the longitudinal feed rate (mm/rev.). N is the rpm and K is the coefficient depending on the specified grade of accuracy and class of surface finish for rough grinding K = 1 to 2 and for finish grinding K = 3 to 5.

Depth of Cut

Depth of cut is the thickness of the layer of the metal removal in one pass. It is measured in mm. normally depth of cut is kept ranging 0.005 to 0.04 mm. Smaller depth of cuts are set for finish and precision grinding.

The table given below shows recommended bonds and cutting speed for type of a work piece.

Type of Work piece	Bond	Cutting Speed
Tool Steel	Vitrified	15 to 25
High Speed Steel	Vitrified	15 to 25
Cemented Carbide	Resin or Rubber	15 to 25

Cast Iron		Up to 30
Steel	Resin or Rubber	Up to 25
Bronze	or	Up to 20
Soft Iron	Vitrified	Up to 20

GRINDING FLUIDS

Application of grinding fluids has been found to be effective in reducing the adverse thermal effects and high work surface temperature. All cutting fluids can be used as coolant in grinding operations and so these can also be named as grinding fluids.

Grinding Normally grinding fluids remove heat from grinding zone and wash the chips away. Generally, two types of grinding fluids are used: (a) Water based fluids, and (b) Oils based fluids. Water based fluids remove heat from grinding zone but these do not provide any lubrication to the grinding zone. However, oil based fluids provide lubrication properties also. Heat removing capability of oil base fluid is more due to their high specific heat. Examples of water based fluids are dissolved chemicals into water like sulfur chlorine, phosphorus, etc. Examples of oil based fluids are oils originated from petroleum, animals and vegetables. They can be emulsified oils suspended in water in the form of droplets. Cutting fluids can be recycled in flow after filtering them by separating out chips and dirt.

DEFECTS AND REMEDIES IN GRINDING

Major and inevitable defects in grinding are glazing of grinding wheels. Its remedy will be discussed later. After the continuous use grinding wheel becomes dull or glazed. Glazing of the wheel is a condition in which the face or cutting edge acquires a glass like appearance. That is, the cutting points of the abrasives have become dull and worn down to bond. Glazing makes the grinding face of the wheel smoother and that stops the process of grinding. Sometimes grinding wheel is left 'loaded'. In this situation its cutting face is found being adhering with chips of metal. The opening and pores of the wheel face are found filled with work piece material particles, preventing the grinding action. Loading takes place while grinding work piece of softer material.

Dressing

The remedies of glazing and loading are dressing of grinding wheels. Dressing removes the loading and breaks away the glazed surface so that sharp abrasive particles can be formed again ready for grinding. Different type of dressing operations are done on a grinding wheel. One of them is the dressing with the help of star dresser. It consists of a number of hardened steel wheels with sharp points on their periphery. The total is held against the face of revolving wheel and moved across the face to dress the whole surface. Another type of wheel dresser consists of a steel tube filled with a bonded abrasive. The end of the tube is held against the wheel and moved across the face.

Truing

Truing is the process of restoring the shape of grinding wheel when it becomes worn and break away at different points. Truing makes the wheel true and concentric with the bore.

BALANCING OF GRINDING WHEEL

Due to continuous used a grinding wheel may become out of balance. It can not be balanced either by truing or dressing. Here it is important to explain the meaning of a balanced wheel. It is the coincidence of center of mass of wheel with its axis of rotation. Wheels which are out of balance produce poor quality of surface and put undue strains on the grinding machine. Balancing of wheel is normally done at the time of its mounting on the grinding machine with the help of moving weights around a recessed flange.
