UNIT 2 GRINDING

Structure

2.1 INTRODUCTION

Grinding is a metal cutting operation performed by means of abrasive particals rigidly mounted on a rotating wheel. Each of the abrasive particals act as a single point cutting tool and grinding wheel acts as a multipoint cutting tool. The grinding operation is used to finish the workpieces with extremely high quality of surface finish and accuracy of shape and dimension. Grinding is one of the widely accepted finishing operations because it removes material in very small size of chips 0.25 to 0.50 mm. It provides accuracy of the order of 0.000025 mm. Grinding of very hard material is also possible.

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.

2.2 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.

2.2.1 Rough Grinding

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

2.2.2 Precision Grinding

Precision grinding removes negligible amount of metal. It is used to produce finished parts and accurate dimensions.

Depending on the geometry of workpiece and the position at which workpiece is to be grind, it can be categorize as external grinding, internal grinding, surface grinding, form grinding and centreless grinding. Each of above categories can be further classified which will be explained below.

On the basis of position of mounting of a grinder it can be categorized as floor stand grinder (which can be installed on the ground); bench grinder, hand grinder, etc.

On the basis of position of spindle, it can be categorized as horizontal spindle environment in which the operation of grinding is done the grinding operation is classified as dry grinding and wet grinding. When cutting fluid is spread over the workpiece, wheel face and sides, it is named as wet grinding. The commonly used cutting fluid is soda water. Temperature of grinding zone reaches upto 2000^{o}C in case of grinding of hard materials. Use of cutting fluid lowers down the temperature and so promotes wheel life. However, in case of dry grinding no coolent is used. It is generally used when workpiece material is not very hard and grinding time is also small. Normally dry grinding produces two undesirable effects discalouration and burring which are eliminated in 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.

2.3 SHAPES AND SIZE OF A GRINDING WHEEL

Grinding wheels are made in different shapes and sizes to adapt them for use in different types of grinding machines and on different classes of work. These are classified in some groups on the basis of shapes and sizes. The shapes of grinding wheels are standardized so that those commonly used in production and tool room grinding may be designated by a number or name or both. Some of the standard grinding wheels are shown below.

2.3.1 Straight Wheel

Some straight wheels are shown in Figure 2.1 Types 1, 2 and 3. These are generally used for cylindrical, internal, centreless and surface grinding operations. These wheels vary in size, diameter and width of the face. All the parameters depend on the clays of work for which the wheel is used, size and power of grinding machine using the wheel.

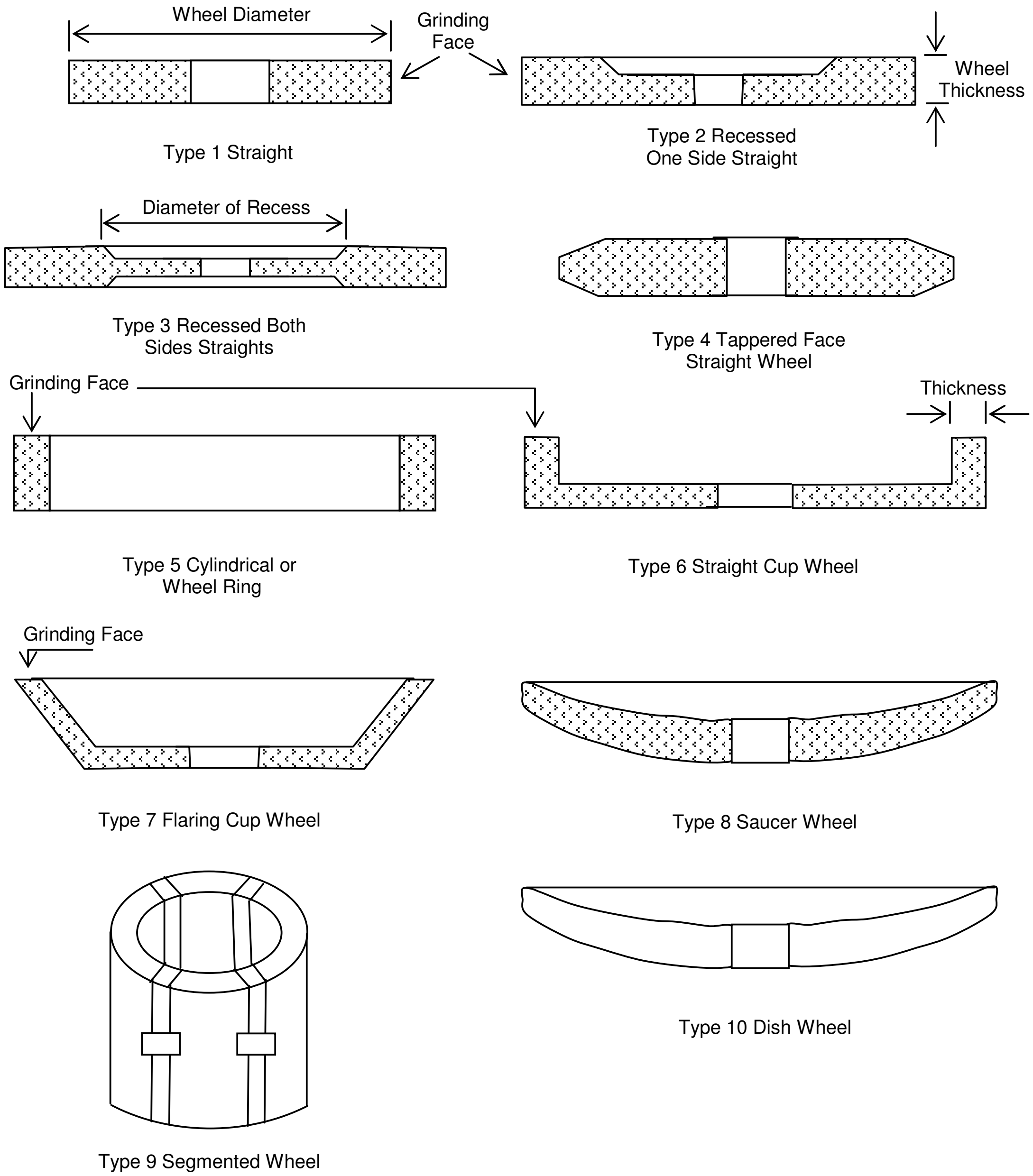

Figure 2.1 : Different Types of Grinding Wheels

2.3.2 Tappered Face Straight Wheels

This is Type 4 in Figure 2.1. It is also a straight wheel but its free is slightly tapered to facilitate the grinding of threads an gear teeth.

2.3.3 Cylindrical Wheel Ring

Cylindrical grinding wheel is shown in Figure 2.1 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.

2.3.4 Cup Wheel

Cup wheel shown in Figure 2.1 Type 6. It is used for grinding flat surfaces with the help of face of grinding wheel.

2.3.5 Flaring Cup Wheel

One modified grinding wheel named as flaring cup wheel is Type 7 in Figure 2.1. It is used in grinding of tools in tool room.

2.3.6 Saucer Wheel

Saucer wheel shown in Figure 2.1 at Type 8. It is used for sharpening of circular or band saw.

2.3.7 Segmented Wheel

Segmented wheel shown in Figure 2.1 at Type 9. These are normally on vertical spindle, rotary type and reciprocating type surface grinders.

2.3.8 Dish Wheel

Dish wheel shown in Figure 2.1 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.

2.3.9 Size of a Grinding Wheel

Major dimensions of a grinding wheel are the out side 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.

2.3.10 Coding of a Grinding Wheel

The Indian Standard Coding system of grinding wheel is IS : 551-1954. 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
17	**:**	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 depends on the manufacturer's choice.

Abrasive Type

This is a alphabet symbol used to indicate the name of abrasive used 'A' stands for Aluminium 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 particals. Larger number indicates finer grain sizes. On the basis of grain size abrasive particals can be categorized in four categories as given below.

Class	Grain Size of Abrasive (Grit)					
Coarse	10	12	14	16	20	24	
Medium	30	36	46	54	60		
Fine	80	100	120	150	180		
Very fine	220	240	280	320	400	500	600

Grain size depends upon quantity of material to the ground required quality of surface finish; and hardness of workpiece material. Find 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	Y	Z

Selection of grade depends on hardness of workpiece material, grinding speed, contact area of grinding wheel with the workpiece, capability of grinding machine. Grinding wheels are named as soft, hard or medium hard wheels depending on their grade. Abrasives of hard grinding wheels get blunt quickly so these are recommended to grind workpiece of low hardness and soft grinding wheels are recommended for hard material workpieces.

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 particals 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.

Type of Structure	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 workpiece 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 particals 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; workpiece material, required bond strength and contact area of workpiece 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.

2.4 VARIOUIS ELEMENTS OF GRINDING WHEEL

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

2.4.1 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 aluminium oxide containing 55 to 65% alumina, rest are iron oxide and impurities. If percentage of aluminium 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. As both of these things influence the performance of grinding wheel adversely.

Artificial Abrasives

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

Silicon Carbide

It is also called carbornudum. It is manufactured from 56 parts of silica sand, 34 parts of powdered cake, 2 pats of salt, 12 parts of saw dust in a long rectangular electric furnace of resistance type. Sand furnishes silicon, cake furnishes carbon, 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 harder than diamond and less tough than aluminium oxide. It is used for grinding of material of low tensile strength like cemented carbide, stone and ceramic, gray cast iron, brass, bronze, aluminium vulcanized rubber, etc.

Aluminium 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. Aluminium 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.

2.4.2 Bonds

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

(a) Vitrified bond,

(b) Silicate bond,

(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 moulded 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. It this way clay vitrifies and fuses to form a porcelain or glass grains. High temperature also does annealing of abrasive. This wheel posses 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 particals with silicate and soda or water glass. It is moulded to required shape, allowed to dried up and then taken out of mould. The raw moulded wheel is baked in a furnace at more than 200^{o}C 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 moulded by rolling and pressing and then by heating upto 150^{o}C for several hours. This bond exhibit 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 aluminium 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 moulded to required shape and baked upto 200^{o}C 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 sulpher. 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 moulded and baked in a furnace to give shape of a grinding wheel. These grinding wheels are used for disc grinding operations. An oxychloride bonded wheel is specified the letter ‘O’.

2.5 PARAMETERS OF GRINDING OPERATION

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

2.5.1 Cutting Speed

Cutting speed is grinding wheel is the relative peripheral speed of the wheel with respect to the workpiece. It is expressed in meter per minute (mpm) or meter per second (mps). The cutting speed of grinding wheel can be calculated as

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

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.

2.5.2 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 workpiece relative to axis of grinding wheel per revolution of grinding wheel. Maximum feed rate should be upto 0.9 time of face width of grinding wheel for rough grinding and upto 0.6 times of face width of grinding wheel for finish grinding. Feed can not be equal to or more than the width of grinding wheel. Feed is used to calculate the total grinding time as given below.

$$T = \frac{L \times i}{S \times N} \times K$$

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 1.2 and for finish grinding K = 1.3 to 1.5.

2.5.3 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 workpiece.

Type of Workpiece	Bond	Cutting Speed (mpm)	
Tool Steel	Vitrified	15 to 25	Precision Grinding
High Speed Steel	Vitrified	15 to 25	
Cemented Carbide	Resin or Rubber	15 to 25	
Cast Iron	Resin or Rubber or Vitrified	Up to 30	Rough Grinding
Steel		Up to 25	
Bronze		Up to 20	
Soft Iron		Up to 20	

2.6 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.

Normally grinding fluids remove heat from grinding zone and wash the clips 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 provides 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.

2.7 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 workpiece material particals, preventing the grinding action. Loading takes place while grinding workpiece of softer material.

Dressing

The remedies of glazing and loading is dressing of grinding wheels. Dressing removes the loading and breaks away the glazed surface so that sharp abrasive particals 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.

2.8 BALANCING OF GRINDING WHEEL

Due to continuous used a grinding wheel may become out of balance. It con 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 centre of mass of wheel with it 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.

2.9 SUMMARY

This unit consists of description of one of the surface finishing operation grinding. Different type of grinding operations along with their commercial applications and types of machine tools used are described here. There is an emphasis upon selection of a suitable grinding wheel depending upon specification of grinding wheel in general and its suitability in a particular type of work. The basic idea of some important quantitative parameters like cutting speed, time to grind a surface, feed rate, etc. is also there in this unit. A little coverage on grinding defects and their solution is also included there in.