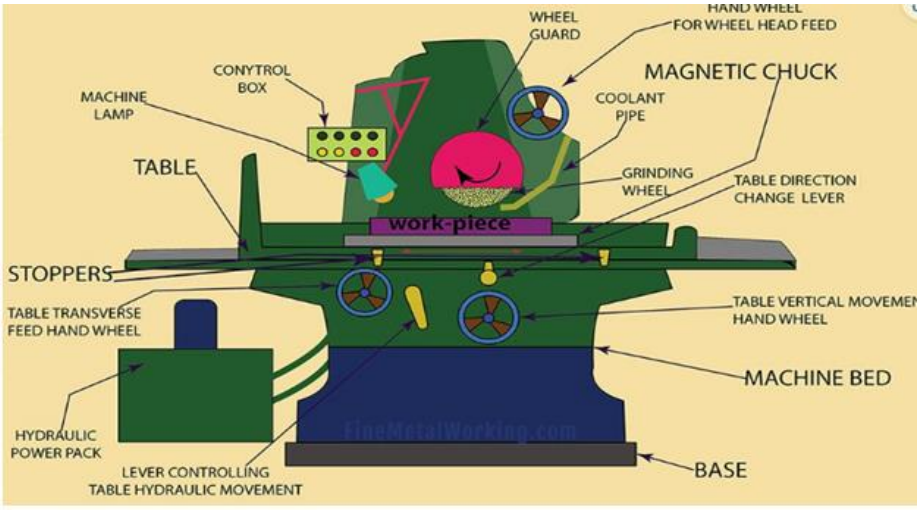
MACHINING

Level-II

Based on March 2022, Curriculum Version 1



Module Title: - Intermediate Grinding Operations

Module code: IND MAC2 M06 0322

Nominal duration: 60Hour

Prepared By: Ministry of Labor And Skill

August 2022

Addis Ababa Ethiopi

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MINISTRY OF LABOR AND SKILLS

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Acknowledgments

Ministry of Labor and Skills wishes to extend thanks and appreciation to the many representatives of TVT instructors and respective industry experts who donated their time and expertise to the development of this Teaching, Training and Learning Materials (TTLM).

Acronyms

ISO. International Standard Organization

IT . International tolerance

TTLM. Teaching, Training and Learning Materials

Introduction to the Module

In **Machining** occupation, **Intermediate Grinding Operations** helps the trainees to identify the different types of grinding machines and opret **Grinding machines** for machining operation. So this **module** helping the trainees to perform grinding opration in order to produce the qulity productes in compitative industry.

This module is designed to meet the industry requirement under **Machining** occupational standard, particularly for the unit of competency: **Intermediate Grinding Operations**

This module covers the units :

- Set up work
- Perform intermediate grinding operations
- Quality assure components in conformance to specifications

Learning Objective of the Module which lets the trainees to:-

- Setting up work
- Performing intermediate grinding operations
- Assure Quality components in conformance to specifications

Module Instruction

For effective use this modules trainees are expected to follow the following module instruction:

1. Read the information written in each unit
2. Accomplish the self-checks at the end of each unit
3. Perform operation sheets which were provided at the end of units
4. Do the “LAP test” given at the end of each unit and
5. Read the identified reference book to get more knowledge as well as to do examples and exercise

Unit One: Set up work

This unit to provide you the necessary information regarding the following content coverage and topics:

- work requirements and sequence of operations
  - Dimensions and tolerances,
  - Geometry
  - Surface finish
- tool ,cutter grinding wheels and balanced.
  - Static
  - Dynamic balancing.
- work holding devices

balancing and dressing grinding wheels

accessories to facilitate production.

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- ✓ Determine work requirements and sequence of operations
- ✓ Select tool and cutter grinding wheels and balanced
- ✓ Select and applying appropriate work holding devices
- ✓ Select, balancing and dressing grinding wheels
- ✓ Select accessories to facilitate production.

1. Set up work

Introduction

This module covers the knowledge, attitudes and skills needed to perform intermediate grinding operations conforming to the required specifications. For performing **Intermediate Grinding Operations**, it is essential to carry out various operations such as ***balancing*** and dressing grinding wheels according to work /operational standard requirements, setting up and adjusting work piece and ***grinding machine*** in accordance with defined standard procedures, performing grinding ***work*** and operations, determining required grade of tolerance, and checking components conformance to specifications and assure its quality etc. are to be performed to make /produce a product of desired shape and size as the given standard.

As a machinist operator you are required to operate grinding machines and to apply techniques, first you have to read and interpret working drawing accurately to determine specifications such as dimensions and machining tolerances, geometry, surface finish, basic metallurgy, basic metrology (calculations and/or formulae) etc. and work requirement for the performing the operations according defined standard procedures and measure manufactured components to specified tolerances using precision measurement equipment

On compilation of the training and though the hands-on practice given, within a self-study environment and the sub course text, you will acquire some of the basic skills and techniques involved with these processes.

1.1.Determining work requirements and sequence of operations

Before starting to any operation, you must plan the sequence of operation /task to be performed, considering factors that affect your working procedure. This you may lead to develop a good product properly saving of time and money.

A work instruction is a tool provided to help someone to do a job correctly. A Work Instruction is the most detailed description of a task. Its purpose is to explain step by step how to do a specific task or work. Work instructions are key to reducing variation, allowing manufacturers to improve quality and meet demand.

One of the characteristics of the skilled worker is the way in which he selects and uses the tools

of his trade. For this reason, it is essential that you know how to select and properly use both the hand and machine tools of the machine trade.

In the work area safety precaution should be observed i.e. safety equipment, protective equipment and others should be observed. Each person should pay attention to own work area. A neat work area reflects a worker's approach to his work and equipment. Good housekeeping begins with panning ahead. Materials should be neatly stacked and any spillages of oil or grease should be cleaned up immediately.

Grinding machine operator job description and duties

The operator or trainer is responsible for setting up and tending grinding machines in order to grind flat surfaces and external or internal cylindrical or tapered surfaces of metal pieces. Follow instructions and charts during grinding procedures from manuals from the respective machine types applying knowledge and skills required in typical activities for grinding machines.

Primary responsibilities:

- Read and interpret charts, drawings, and blueprints.
- Determine product specifications such as dimensions, tolerances, and number of parts to be ground.
- Observe and identifying or obtaining information from all relevant sources to arrange things or actions in a certain order or pattern according to a specific rule or set of rules (e.g., patterns of numbers, letters, words, pictures, mathematical operations) by estimating, recognizing differences or similarities, and detecting changes in circumstances or events.
- Specifications are usually analyzed for limited runs, on knowledge of raw materials, production processes, quality control, costs, and other techniques for maximizing the effective manufacturing of the components.
- Visualize grinding to be done and plans sequence of operations
- Selects machine tool and equipment to be used in operation, utilizing knowledge of machine and production requirements for required products
- Determine grinding speeds, feed rates, for each operation according to knowledge of metal properties and abrasives
- Determine holding fixtures, and grinding wheels to be used.
- Check grinding wheels for cracks and change worn grinding wheels.
- Mount grinding wheel on spindle
- Dress wheel according to specifications using dressing devices.
- Lift or hoist work pieces, mount and position work piece on magnetic chuck, in holding fixture, or directly to machine table or other tool holding device to specifications
- Positions and tightens stops to limit table travel.

- Position work rest to specified height.
- Adjust machine controls and reads dials to index work piece for specified dimension and base reference points for pre-selected operational settings.
- Activates machine start-up switches to grind or cut work piece, according to specifications.
- Set up automatic work-feeding device.
- Moves controls to feed work piece to wheel or vice versa.
- Turns valve handle and directs flow of coolant against wheel and work piece.
- Grind rough and finish of flat, external or internal cylindrical, tapered and/or conical surfaces on metallic and/or nonmetallic materials by the application of a rotating abrasive wheel and use proper wheel guards on all grinding machines
- Observe the machine during operation and make sure the grinding machine is working properly, watching gauges, dials, or other indicators
- Inspects or measures work piece, using precision measuring instruments or devices, such as calipers, micrometers or gauges for conformance to specifications and identify errors or other problems or defects.
- Maintain, adjust, repairs or replaces machine parts and tools by monitoring and reviewing or detecting the problems. Notify engineering personnel when corrective action or routine maintenance is required.
- May dress grinding wheel to specified profile for contour grinding, using special fixtures and tools.

Sequence of operations

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- Inspects or measures work piece, using precision measuring instruments or devices, such as calipers, micrometers or gauges for conformance to specifications and identify errors or other problems or defects.
- Maintain, adjust, repairs or replaces machine parts and tools by monitoring and reviewing or detecting the problems. Notify engineering personnel when corrective action or routine maintenance is required.
- May dress grinding wheel to specified profile for contour grinding, using special fixtures and tools.

1.1.1.Dimensions and tolerances,

The manufacture of interchangeable parts requires precision. Precision is the degree of accuracy to ensure the functioning of a part as intended. However, experience shows that it is impossible to make parts economically to the exact dimensions. This may be due to inaccuracies of machines and tools, inaccuracies in setting the work to the tool, and error in measurement, etc. The workman, therefore, has to be given some allowable margin so that he can produce a part, the dimensions of which will lie between two acceptable limits, i.e. a maximum and a minimum permissible limits of the given size. The system in which a variation is accepted is called the **limit system** and the allowable deviations are called **tolerances**.

Great care and judgement must be exercised in deciding the tolerances which may be applied on various dimensions of a component. If tolerances are to be minimum, that is, if the accuracy requirements are severe, the cost of production increases. In fact, the actual specified tolerances dictate the method of manufacture. Hence, maximum possible tolerances must be recommended wherever possible.

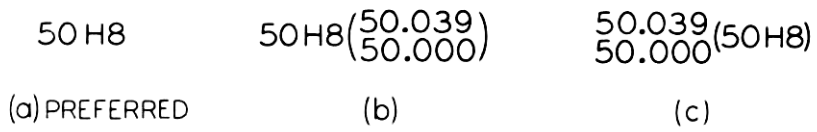
The range of **tolerance grades** that grinding processes expected to produce under normal conditions as indicated by the IT grades in micron (1 micron = 0.001 mm) is given as 5 and 7 for Cylindrical grinding and 5 and 8 for Surface grinding.

International tolerance (IT) grade is a set of tolerances that varies according to the basic size

and provides a uniform level of accuracy within the grade.

The **tolerances** that are normally achieved with grinding are $\pm 2 \times 10^{-4}$ inches for a grinding a flat material, and $\pm 3 \times 10^{-4}$ inches for a parallel surface. Tolerances for cylindrical grinding are held within five/ten-thousandths of an inch (+/- 0.0005) for diameter and one/ten-thousandth of an inch (+/- 0.0001) for roundness. Modern grinding machines grind hard or soft parts to tolerances of plus or minus 0.0001 inch (0.0025 millimetre).

For example, the dimension 50H8 for a close-running fit, the IT grade is indicated by the numeral 8. Acceptable Methods of Giving Tolerance Symbols:



Example: If an allowance of 0.05 mm for clearance is applied, say to a shaft of 50 mm diameter, then its design size is (50 – 0.05) = 49.95 mm. A tolerance is then applied to this dimension.

Table 1:1 The fundamental tolerances of grades

Basic size (Diameter steps) in mm		*Standard tolerance grades, in micron (1 micron = 0.001 mm)*																	
		IT01	IT0	IT1	IT2	IT3	IT4	IT5	IT6	IT7	IT8	IT9	IT10	IT11	IT12	IT13	IT14	IT15	IT16
Over	1	0.3	0.5	0.8	1.2	2	3	4	6	10	14	25	40	60	100	140	250	400	600
To and inc.	3																		
Over	3	0.4	0.6	1	1.5	2.5	4	5	8	12	18	30	48	75	120	180	300	480	750
To and inc.	6																		
Over	6	0.4	0.6	1	1.5	2.5	4	6	9	15	22	36	58	90	150	220	360	580	900
To and inc.	10																		
Over	10	0.5	0.8	1.2	2	3	5	8	11	18	27	43	70	110	180	270	430	700	1100
To and inc.	18																		
Over	18	0.6	1	1.5	2.5	4	6	9	13	21	33	52	84	130	210	330	520	840	1300
To and inc.	30																		
Over	30	0.6	1	1.5	2.5	4	7	11	16	25	39	62	100	160	250	390	620	1000	1600
To and inc.	50																		
Over	50	0.8	1.2	2	3	5	8	13	19	30	46	74	120	190	300	460	740	1200	1900
To and inc.	80																		
Over	80	1	1.5	2.5	4	6	10	15	22	35	54	87	140	220	350	540	870	1400	2200
To and inc.	120																		
Over	120	1.2	2	3.5	5	8	12	18	25	40	63	100	160	250	400	630	1000	1600	2500
To and inc.	180																		
Over	180	2	3	4.5	7	10	14	20	29	46	72	115	185	290	460	720	1150	1850	2900
To and inc.	250																		
Over	250	2.5	4	6	8	12	16	23	32	52	81	130	210	320	520	810	1300	2100	3200
To and inc.	315																		
Over	315	3	5	7	9	13	18	25	36	57	89	140	230	360	570	890	1400	2300	3800
To and inc.	400																		
Over	400	4	6	8	10	15	20	27	40	63	97	155	250	400	630	970	1550	2500	4000
To and inc.	500																		

1.1.2.Geometry

Grinding Wheel Geometry

GW shapes must permit proper contact between the wheel and the surfaces to be ground.

Figure 1. illustrates eight standard shapes of GWs, whose applications are as follows:

Types of grinding wheels Shapes and Segments

Grinding wheels are available in a wide range of shapes, sizes, and abrasives. For most wheel shapes, the correct wheel shape can be selected from these standard configurations (accepted as ANSI B74.2). Some of the most popular standard types are listed below.

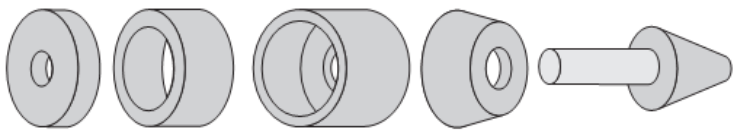


Figure 1:1 Some common types of grinding wheels; (From left to right) straight, cylinder,

straight cup, flaring cup, mounted.

The straight wheel is the most common mode of a wheel that is found on pedestal or bench grinders.

This is the one widely used for centreless & cylindrical surface grinding operations. As it is used only on the periphery, it forms a little concave surface on the piece.

This is used to gain on several tools like chisels.

The size of these wheels differs to a great extent, width & diameter of its face obviously depends on the category of its work, machines grinding power.

Cylinder or wheel ring Grinding wheels: a cylinder wheel has no center mounting support but has a long & wide surface.

Their width is up to 12″ and is used purely in horizontal or vertical spindle grinders.

This is used to produce a flat surface, here we do grinding with the ending face of the wheel

.A tapered Grinding wheel is a straight wheel that tapers externally towards the midpoint of the wheel.

As this pact is stronger than straight wheels, it accepts advanced lateral loads.
The straight wheel with a tapered face is chiefly used for gear teeth, grinding threads, etc

Straight cup Grinding wheels: Straight cup wheel forms an option for cup wheels in cutter and tool grinders, having an extra radial surface of grinding is favorable

Flaring Cup wheel, is commonly used for tool grinding. With a resinoid bond, it is useful for snagging. Its face may be plain or bevelled.

Dish cup grinding wheels: In fact, this is used primarily in jig grinding and cutter grinding.

It is a very thin cup-style grinding wheel which permits grinding in crevices and slot. its chief use is in tool work. Its thin edge can be inserted into narrow places, and it is convenient for grinding the faces of form-relieved milling cutters and broaches.Saucer Grinding Wheel is an exceptional grinding profile used for grinding twist drills and milling cutters.

This finds wide usage in non-machining areas, as these saw filers are used by saucer wheels to maintain saw blades.

Diamond Grinding wheels:-In diamond wheels, industrial diamonds remain bonded to the edge.

This is used to grind hard materials like concrete, gemstones & carbide tips. A slitting saw is designed for slicing gemstones like hard materials. Some of the most popular standard types are listed below.

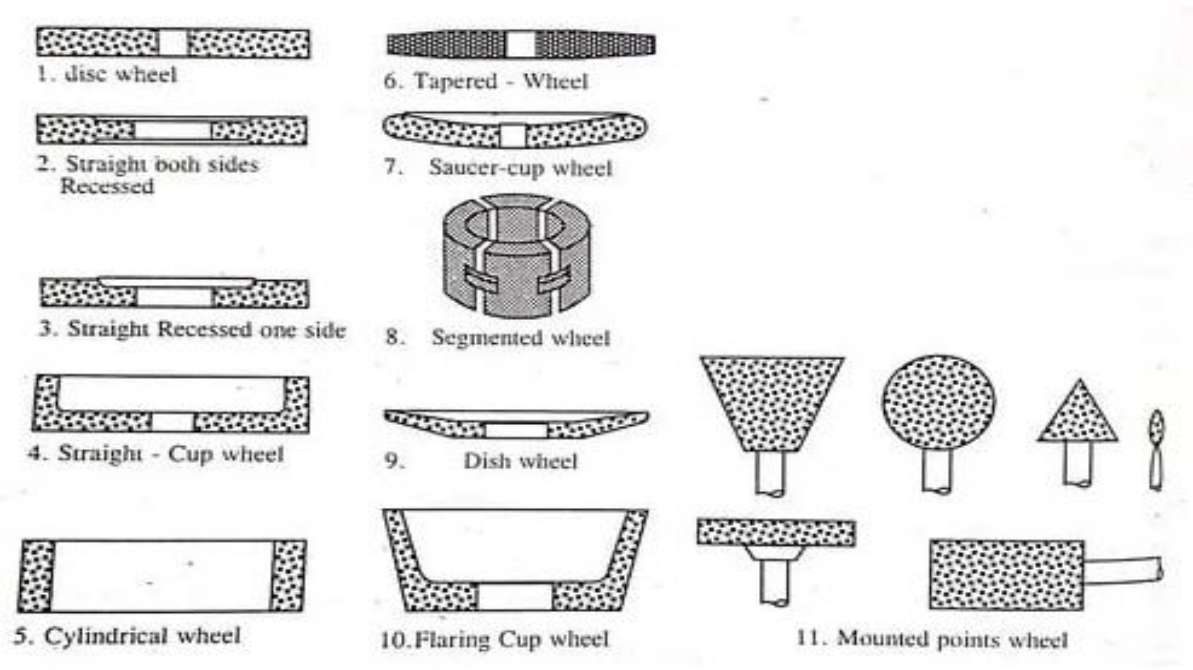


Figure 1.2. Diagram of all types of grinding wheels

Shapes 1, 3 and 5 are intended for grinding external or internal cylindrical surfaces and for plain surface grinding.

- ✓ Shape 2 is intended for grinding with the periphery or the side of the wheel.
- ✓ Shape 4 is of a safely tapered shape to withstand breakage during snagging.
- ✓ Shape 6 is a straight cup intended for surface grinding.
- ✓ Shape 7 is a flaring cup intended for tool sharpening.
- ✓ Shape 8 is a dish type intended for sharpening cutting tools and saws.

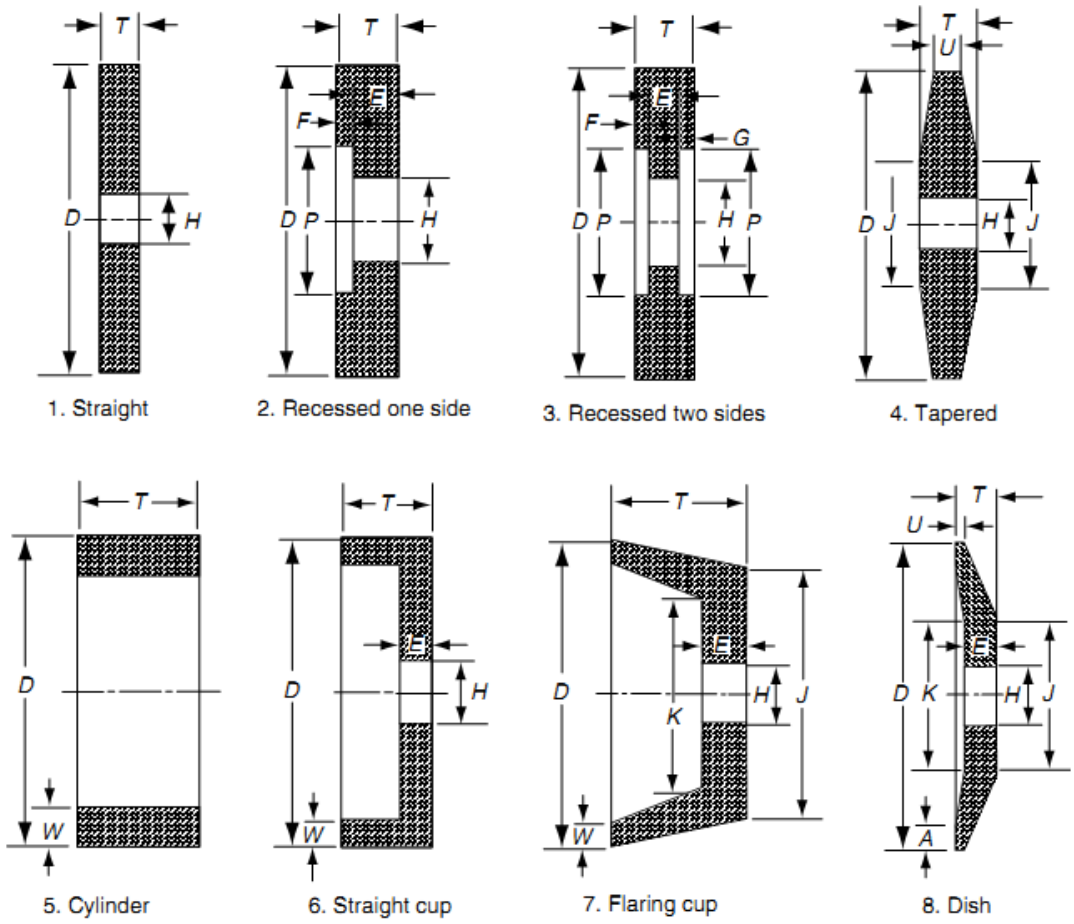


Figure 1.3. Standard types of grinding wheels

Standard shapes of grinding wheel faces

The nature of the work dictates the shape of the grinding wheel face to be used. Each shapes of GWs has a specific grinding surface. Grinding on other faces is improper and unsafe. For instance, shape A is commonly used for straight cylindrical grinding and shape E for grinding threads. Figure 20. shows a variety of standard face contours for the straight GWs.

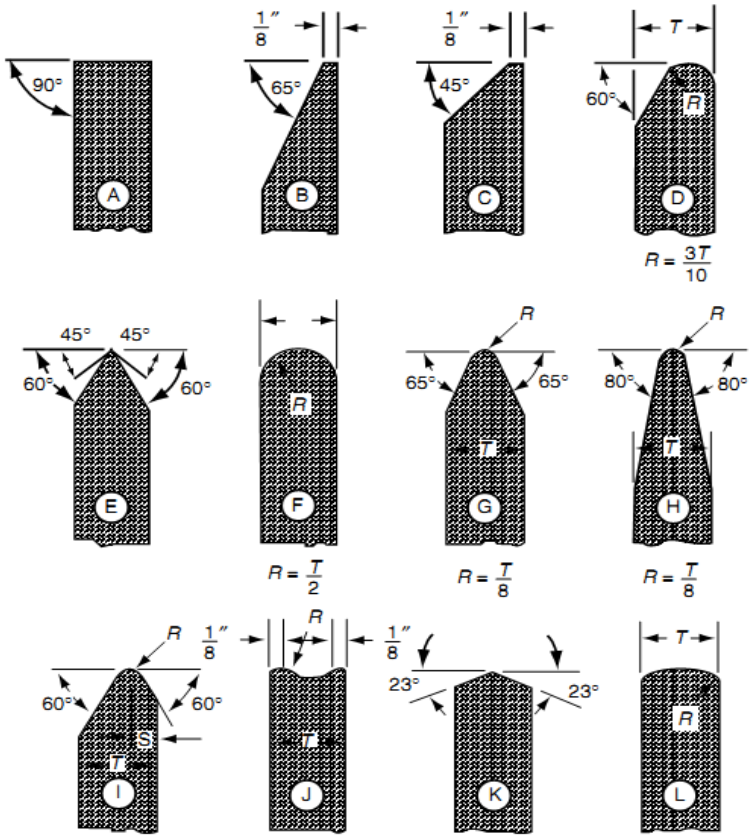


Figure 1.4 Standard face contours of a straight-shape grinding wheels.

1.1.3.Surface finish

Surface finish is intimately related to the functioning of a surface, and proper specification of finish of such surfaces as bearings and seals is necessary. Surface quality specifications should be used only where needed, since the cost of producing a finished surface becomes greater as the quality of the surface called for is increased. Generally, the ideal surface finish is the roughest one that will do the job satisfactorily.

Abrasive grinding operations are performed to achieve a surface finish, which cannot be achieved by conventional machining processes. According to Indian standards, surface roughness (Ra) that grinding processes (Cylindrical and Surface) expected to produce under normal conditions is as 0.063 to 5 in micron (1 micron = 0.001 mm) is given as 5 and 7 for Cylindrical grinding and 5 and 8 for Surface grinding.

Surface finishes that grinding processes produce can range from 2 to 125 micro inches, with typical finishes ranging from 8-32 micro inches. Grinding operation is capable of producing

surface finish as good as less than 1 μm (say, 0.75 μm). The ultimate surface finish in grinding with fine grit size is about 0.2 μm.

The surface finish is basically ratified by grinding wheel and process parameters.

Abrasive grain size: smaller grit size will produce lower surface roughness;

Structure: denser structure of the grinding will, i.e., more abrasive grains per cubic millimetre will increase the number of active grains in contact with the work surface thus improving the surface finish;

Cutting velocity: The surface finish will be improved by increasing the number of abrasive grains per unit time, therefore by increasing the cutting speed.

Effects of Grinding Temperatures on Work piece Materials

Temperature rise in grinding can significantly affect surface properties and the influence of the cutting temperature cannot be omitted. Furthermore, the heat generated and conducted into the workpiece expands the workpart and causes dimensional errors. Grinding process parameters must therefore be chosen carefully to avoid excessive temperature rise. The use of grinding fluids can effectively control cutting temperatures.

Table 1.2: Effects of grinding temperatures on workpiece materials

Material Property	**Effects of Grinding**
Mechanical	• Residual surface stresses • Possible forming of a thin martensitic layer on surface • Reduced fatigue strength
Physical	• Possible loss of magnetic properties on ferromagnetic materials
Chemical	• May increase susceptibility to corrosion because of high surface stress

Mechanical properties will change due to stresses put on the part during finishing. High grinding temperatures may cause a thin martensitic layer to form on the part, which will lead to reduced material strength from microcracks.

Tempering: excessive temperatures can temper and soften the material on the surfaces, which is often ground in the hardened state.

Burning: if the temperature is excessive the surface may burn. Burning produces a bluish color on steels, which indicates high temperature oxidation with all the negative changes in the surface material properties.

Thermal cracks: high temperatures may also lead to thermal cracking of the surface of the workpiece. Cracks are usually perpendicular to the grinding direction; however, under severe grinding conditions, parallel cracks may also develop.

Residual stresses: temperature change and gradients within the workpiece are mainly responsible for residual stresses in grinding.

Table 1.3: Common Grinding Damages: Faults, Failures, and Cures

Fault Description	**Probable Failure**	**Possible Cure**
Excessive stock removal rate causing heating of the part surface beyond the applied tempering temperature	Scorched tool surface displaying temper colors varying from yellow to purple, depending on the degree of heat, causes softening of the ground surface. When coolant is used, a local rehardening can take place, often resulting in cracks.	Prevention: by reducing speed and feed, or using coarser, softer, more open-structured grinding wheel, with ample coolant. Correction: eliminate the discolored layer by subsequent light stock removal. Not always a cure, because the effects of abusive grinding may not be corrected.
Improper grinding wheel specifications; grain too fine or bond too hard	Intense localized heating during grinding may set up surface stresses causing grinding cracks; either parallel but at right angles to the direction of grinding or, when more advanced, form a network. May need cold etch or magnetic particle testing to become recognizable.	Prevention: by correcting the grinding wheel specifications. Correction: in shallow (0.002- to 0.004-inch) cracks, by removing the damaged layer, when permitted by the design of the tool, using very light grinding passes.
Incorrectly dressed or loaded grinding wheel	Heating of the work surface can cause scorching or cracking. Incorrect dressing can also cause a poor finish of the ground work surface.	Dress wheel with sharper diamond and faster diamond advance to produce coarser wheel surface. Alternate dressing methods, like crush-dressing, can improve wheel

		surface conditions. Dress wheel regularly to avoid loading or glazing of the wheel surface.
Inadequate coolant, with regard to composition, amount, distribution, & cleanliness	Introducing into the tool surface heat that is not adequately dissipated or absorbed by the coolant can cause softening, or even the development of cracks.	Improve coolant supply and quality, or reduce stock removal rate to reduce generation of heat in grinding.
Damage caused by abusive abrasive cutoff	The intensive heat developed during this process can cause a hardening of the steel surface, or may even result in cracks.	Reduce rate of advance; adopt wheel specifications better suited for the job. Use ample coolant or, when harmful effect not eliminated, replace abrasive cutoff by some cooler-acting stock separation method (e.g., sawing or lathe cutoff) unless damaged surface is being removed by subsequent machining.

1.2.Selecting tool and cutter grinding wheels and balanced.

1.2.1 Static

Static Balancing

Static balancing refers to the balance point of an object around its axis of rotation.

What this means is that if you were to mount the any object on a free rotating axle, then it would remain stationary regardless of its position it was left in.

If an object has a static imbalance then when mounted to a rotating axis, the heavy spot of the wheel will want to fall to the bottom

By placing the matching weight on the opposite side of the heavy spot, the imbalance can be dialed out. This very principal has led to the method developed and used to balance motorcycle rims and narrow vintage car wheels for many years. The wheels are mounted onto a shaft which then freely rotates between two bearings. Any heavy spot will rotate and settle at the bottom of the frame, you would then apply a small amount of weight directly opposite i.e. at the top. You would then rotate the wheel a bit and let go, then “Rinse & Repeat” the previous process until the wheel no longer moves when you let it go.

1.2.2. Dynamic balancing.

In order to explain Dynamic Imbalance, we need to examine part of **Newton's first law of motion** "***an object in motion stays in motion with the same speed and in the same direction unless acted upon by an unbalanced force"***.

Now without getting into a physics lesson (and as a pre-empt …. any technical people still present, please take a chill pill and calm down for a moment I know you want to shout, but we're trying to keep it simple) what this means is as follows

Take a piece of cord, string or fishing line and attach a weight to one end. Now start to spin that weight around your hand in a continual fashion. You will see the weight turning around a central point, specifically around the point of which the force is applied i.e., it spins around your hand

Now if you let go of the string you would see Newton^{s} law come into play and the weight would fly off (in the direction it was traveling in, at the point in which you let go .But rather than letting go if you were to hold onto the string and allow the weight to freely rotate instead, then the Centripetal force or centrifugal force (depending on your point of reference) will act on it and you will feel the weight pulling your arm towards the weight (making your hand move and down) this is the static Imbalance.

1.3.Selecting and applying appropriate work holding devices

The job or work piece and the cutting tools essentially need to be properly mounted in the machine tool for achieving desired performance of the machining system. The work is held in the various types of work holding devices like three jaw chuck, four jaw chuck, combination chuck, magnetic chuck, hydraulic chuck, face plate, driving plate, angle plate and lathe carriers. The work holding method affects the production time as it changes set up times.

The principal methods of holding work for grinding in a plain or universal cylindrical grinding machine are between centers, and in a chuck or on a faceplate. In most surface grinding operations, a workpiece is usually held to the reciprocating worktable by a magnetic chuck, a universal vice or clamped directly to the table.

Magnetic chuck

The **chuck** is a work-holding device (either electromagnetic or vacuum), that is used to hold the material in place while it is being worked on. It can do this one of two ways; metallic pieces are held in place by a magnetic chuck, while nonmetallic pieces are vacuumed in place. The two types of magnetic chucks are permanent magnet and electric. The electric chucks are built in larger sizes and are more powerful. However, the permanent-magnet chucks are less dangerous, since accidental release of work (due to power failure) is not likely to occur.

Much work done on a surface grinder is flat work pieces, it is held in position by a **magnetic chuck**, Figure 29. This holds the work by exerting a magnetic force. Demagnetizer can be used to neutralize part after being clamped in magnetic chuck. Frequently, work mounted on a magnetic chuck comes magnetized and must be demagnetized before it can be used. The use of a permanent magnet eliminates cords needed for electromagnets and the danger of electrical connection being broken accidentally permitting work to fly off the chuck. For either chuck, work will not remain in place unless it contacts at least two magnetic poles of the chuck.

You cannot hold nonmagnetic materials in a magnetic chuck unless you use special setups. **Non-magnetic materials** (aluminum, brass, etc.) can be ground by bracing with steel blocks or parallels to prevent movement. Double-faced masking tape can be used to hold thin sections of nonmagnetic materials.

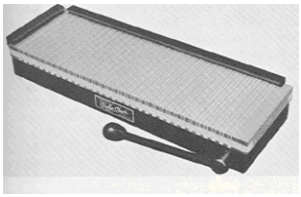


Figure 1.5፡- Magnetic chuck

Universal vice:

universal vise usually used when complex angles are needed to be grind on a work piece. It be can mounted directly on the worktable of the grinder or on the magnetic chuck and set up the work by rotating the swivel base through 360° in a horizontal plane and the intermediate swivel, so you can position the surface to be ground at any angle.

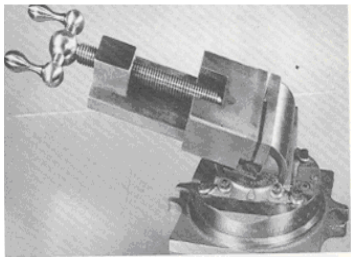


Figure 1.6. A universal Vise

Chuck and faceplate

Chucks and faceplates are used in a similar manner to those used on a lathe.

1. Four-jaw independent chucks and
2. Three-jaw chucks with reversible jaws
3. An indexing head with centers

Faceplates are often used for work that cannot be readily held in a chuck and are commonly used for holding work requiring internal grinding operations. The work piece is fixed to the faceplate with clamps and packing pieces of the correct height can be used to provide clearance for the grinding wheel.



Figure 1.7. four jaw, three jaw and Face plate

Other ways to mount work on a surface grinder:

The work piece is manually clamped to a **lathe dog**, powered by the faceplate, that holds the piece in between two centers and rotates the piece. The piece and the grinding wheel rotate in opposite directions and small bits of the piece are removed as it passes along the grinding wheel. In some instances special drive centers may be used to allow the edges to be ground.

Table 1.4: Work-Holding Methods and Devices for Cylindrical Grinding

Designation	**Description**	**Discussion**
Centers, nonrotating (“dead”), with drive plate	Headstock with nonrotating spindle holds the center. Around the spindle, an independently supported sleeve carries the drive plate for rotating the work. Tailstock for opposite center.	The simplest method of holding the work between two opposite centers is also the potentially most accurate, as long as correctly prepared and located center holes are used in the work.
Centers, driving type	Word held between two centers obtains its rotation from the concurrently applied drive by the live headstock spindle and live tailstock spindle.	Eliminates the drawback of the common center-type grinding with driver plate, which requires a dog attached to the workpiece. Driven spindles permit the grinding of the work up to both ends.
Chuck, geared, or cam-actuated	Two, three, or four jaws moved radially through mechanical elements, hand-, or power-operated, exert concentrically acting clamping force on the workpiece.	Adaptable to workpieces of different configurations and within a generally wide capacity of the chuck. Flexible in uses that, however, do not include high-precision work.
Chuck, diaphragm	Force applied by hand or power of a flexible diaphragm causes the attached jaws to deflect temporarily for accepting the work, which is held when force is released.	Rapid action and flexible adaptation to different work configurations by means of special jaws offer varied uses for the grinding of disk-shaped and similar parts.
Collets	Holding devices with externally or internally acting clamping force, easily adapt-able to power actuation, assuring high centering accuracy.	Limited to parts with previously machined or ground holding surfaces, because of the small range of clamping movement of the collet jaws.
Face plate	Has four independently actuated jaws, any or several of which may be used, or entirely removed, using the base plate for supporting special clamps.	Used for holding bulky parts, or those of awkward shape, which are ground in small quantities not warranting special fixtures.

Magnetic plate	Flat plates, with pole distribution adapted to the work, are mounted on the spindle like chucks and may be used for work with the locating face normal to the axis.	Applicable for light cuts such as are frequent in tool making, where the rapid clamping action and easy access to both the O.D. and the exposed face are some-times of advantage.
Steady rests	Two basic types are used: (a) the two-jaw type supporting the work from the back (back rest), leaving access by the wheel; (b) the three-jaw type (center rest).	A complementary work-holding device, used in conjunction with primary work holders, to provide additional support, particularly to long and/or slender parts.
Special fixtures	Single-purpose devices, designed for a particular workpiece, primarily for providing special locating elements.	Typical workpieces requiring special fixturing are, as examples, crankshafts where the holding is combined with balancing functions; or internal gears located on the pitch circle of the teeth for O.D. grinding.

General Method of mounting the work piece in the machine tool

Offhand grinding requires no mounting of the work piece. Mounting for cylindrical and surface grinding is described below.

1. First of all, appropriate selection of work holding device or system from the available resources depending upon;
   - Configuration of the machine tool
   - Shape, size and weight of the blank
   - Kind of machining work to be done
   - Order of dimensional accuracy desired
   - Volume (number of same job) of production
2. Secondly correct location, strong support and rigid clamping of the work piece against the cutting and other forces.
3. Thirdly easy and quick loading and unloading to and from the machine tool or the holding device
4. Fourth proper alignment like coaxiality, concentricity etc. of rotating jobs
5. Finally, free flow of chips and cutting fluid.

1.4.Selecting, balancing and dressing grinding wheels

Wheel Balancing and Dressing

Wheel Balancing:

Because of the high rotational speeds involved, GWs must never be used unless they are in good balance. A slight imbalance produces vibrations that cause waviness errors and harm the machine parts. This may cause wheel breakage, leading to serious damage and injury. **Static unbalance** of a GW is necessary due to the lack of coincidence between its center of gravity and its axis of rotation. Lack of balance is measured at the manufacturing plant in special balancing machines and is eliminated. The user balances GWs either on a balancing stand or directly in the grinder. Best results are achieved by **dynamically balancing** the wheel.

In the case of balancing GW on balancing stand and before mounting the wheel on the spindle, each wheel with its sleeve should be balanced on an arbor that is placed on the straight edges or revolving disks for a balancing stand (Figure 24). The wheel is balanced by shifting three balance weights (1) in an annular groove of the wheel sleeve (or mounting flange). Other way is to adjust the position of the slotted weights provided in the rim of the flange. These adjustable segments can be fixed round a circle at any position by tightening the screws. The wheel is rotated until it no longer stops its rotation at a specific position. Certain grinders are equipped with a mechanism for balancing the wheel during operation without stopping the wheel spindle rotation.

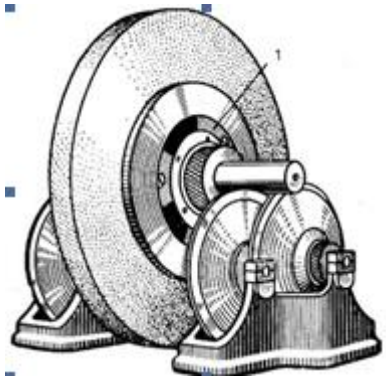


Figure 1.8፡- Revolving-disk wheel balancing stand.

Wheel Truing and Dressing

During the grinding process some of the sharp edged abrasive grains become dull (glazed). The grain may not fracture as they should to provide new, sharp cutting edges. Also, metal particles

from the workpiece or tool may become embedded in the wheels. Such a wheel is said to be loaded and must be dressed. So as to make sure the shape of the wheel is what you want.

Dressing is the process of reconditioning of a grinding wheel. Reconditioning a wheel is necessary for efficient grinding and to produce a good quality of surface finish. Dressing is cutting the face of a grinding wheel to restore its original cutting qualities. Truing is restoring the wheel's concentricity or reforming its cutting face to a desired shape. Hand dressers are used for both dressing and truing grinding wheels. From time to time it will be necessary to dress a wheel in use, to open up the pores and remove any dull abrasive grain or clogging metal from the wheel face, thus presenting fresh sharp grains which will cut better and generate less heat. Always ensure that the wheel guards are securely in place before attempting to dress or true a grinding wheel. Goggles or other suitable eye protection should always be worn when using the machine.

Three mechanisms are recognized as the principal causes of wear in grinding wheels:

grain fracture (the breaking away of parts of the grain, yielding new sharp edges),

attrition wear (dulling of the individual grain), and

bond fracture (the dislodging of the grains from the wheel through the fracture of their bonds).

Grain fracture occurs when a portion of the grain breaks off but the rest of the grain remains bonded in the wheel. The edges of the fractured area become new sharp cutting edges on the grinding wheel. This makes the grinding wheel self-sharpening, a unique property of a cutting tool.

Attritious wear involves dulling of the individual grains, resulting in flat spots and rounded edges. Attritious wear is analogous to tool wear in a conventional cutting tool.

Bond fracture occurs when the individual grains are pulled out of the bonding material. Bond fracture usually occurs because the grain has become dull due to attritious wear and the resulting cutting force is excessive. Sharp grains cut more efficiently with lower cutting forces; hence, they remain attached in the bond structure.

Dressing is needed under the following conditions **…**

- An even chatter surface is produced.
- The workpiece is heated excessively during grinding.

- Coloured burn marks appear on the work surface.

There is considerable vibration when the wheel is in contact with the workpiece.

There are load lines on the workpiece that indicate the wheel is loaded with metal particles.

Mechanical (hand) wheel dressers

Mechanical wheel dressers are usually used for heavier dressing and truing operations. They are designed with many different forms of metal wheels discs. These discs are mounted on a shaft at one end of a hand holder. The discs have star or wavy parrerns. They are made of hardened steel and are replaceable. These circular discs faces are brought into contact with the face of the grinding wheel, they turn at considerable velocity in comparison to the speed of the grinding wheel. The action between the dresser discs and the grinding wheel causes the abrasive grains to fracture. New cutting edges are exposed, the embedded particles are torn out. A dresser, guided under more controlled conditions, is used to true a grinding wheel to a finer degree of accuracy.

The **hand-held mechanical dresser** has alternate pointed and solid discs which are loosely mounted on a pin. This dresser is used to dress coarse-grit wheels and wheels used in hand grinding operations.

The **abrasive stick dresser** comes in two shapes: square for hand use, and round for mechanical use. It is often used instead of the more expensive diamond dresser for dressing shaped and form wheels. It is also used for general grinding wheel dressing.

The **abrasive wheel dresser** is a bonded silicon carbide wheel that is fastened to the machine table at a slight angle to the grinding wheel and driven by contact with the wheel. This dresser produces a smooth, clean-cutting face that leaves no dressing marks on the work.

Caution: Extreme care must be taken when hand dressing. The grinding wheel guard and shield must be in place, the work rest must be correctly positioned to support and serve as a guide for the dresser, and personal goggles must be worn.

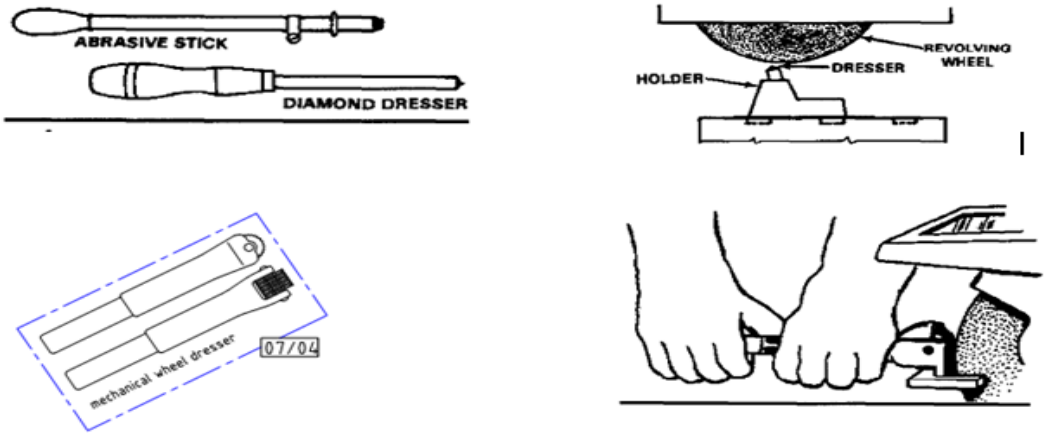


Figure 1.9. hand-held wheel Dressing tool

Diamond wheel dressing tool

When surface grinding an object, one must keep in mind that the ***shape of the wheel*** will be transferred to the material of the object like a mirror image. It is common practice to what is called "***dress***" the stone. This is done by using a **diamond** to remove the abrasive material not wanted and to give the desired geometry.

The diamond dressing tool should be clamped firmly, as close as possible to the diamond, in the universal tooth rest in place of the tooth rest post. Insecurity or excessive overhang induces vibration and chatter which is detrimental to the work and the diamond. The diamond should touch on the wheel axis centre line with the diamond axis inclined at about 10^0 degrees to give "drag" effect or trailing cut.

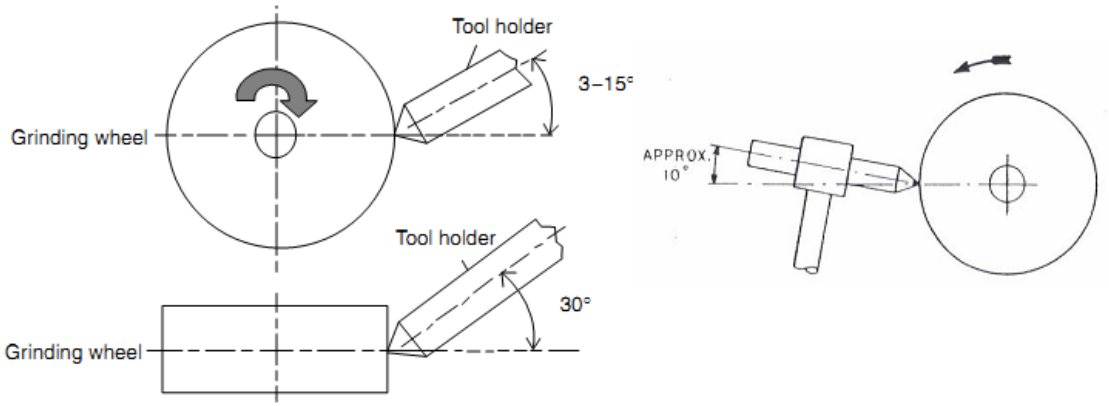


Figure 1.10:- Diamond truing and dressing of GWs and Depth of cut

Depth of cut should not be greater than '005", decreasing on subsequent passes according to the wheel finish required. Table traverse should not be too rapid and the approach of diamond to wheel should be made carefully to avoid shattering the diamond.

Always ensure that the wheel guards are securely in place before attempting to dress or true a grinding wheel. Goggles or other suitable eye protection should always be worn when using the machine.

Factors in dressing

Dressing is intended to regenerate a grinding wheel that can no longer be used for grinding. The ability of a wheel to perform its function of producing the required dimensional and geometric accuracy and surface finish on the work piece depends substantially on the dressing process. Figure 11 shows a schematic of the size relationships in dressing by means of a cross-section of a grinding wheel that is being ‘machined’ by a form dresser. Starting with a wheel of grain size 100 (corresponding to an average grain size of approx. 110-150 µm), dressing amounts of approx. 30- 100 µm are removed from the wheel. This corresponds roughly to a layer of abrasive, i.e. a completely new abrasive layer has been generated and is available for the next grinding stage. When dressing a wheel for finishing operations, about 10-20 µm is removed from the surface. This means that only some of the abrasive layer is regenerated by splintering or breaking out to provide new, sharp cutting edges for a free-cutting grinding wheel topography.

The objective in dressing, by an optimum selection of the set-up values – such as the depth of cut

and the dresser infeed and through optimum conditions for the dresser, is not to damage the surface structure of the grinding wheel. If the dressing forces are too high, this can result in damage in the form of cracking of the abrasive or damage to the bond, thereby leading to premature break-out of the abrasive grains. Damage such as this results in reduced wheel life and shorter dressing intervals.

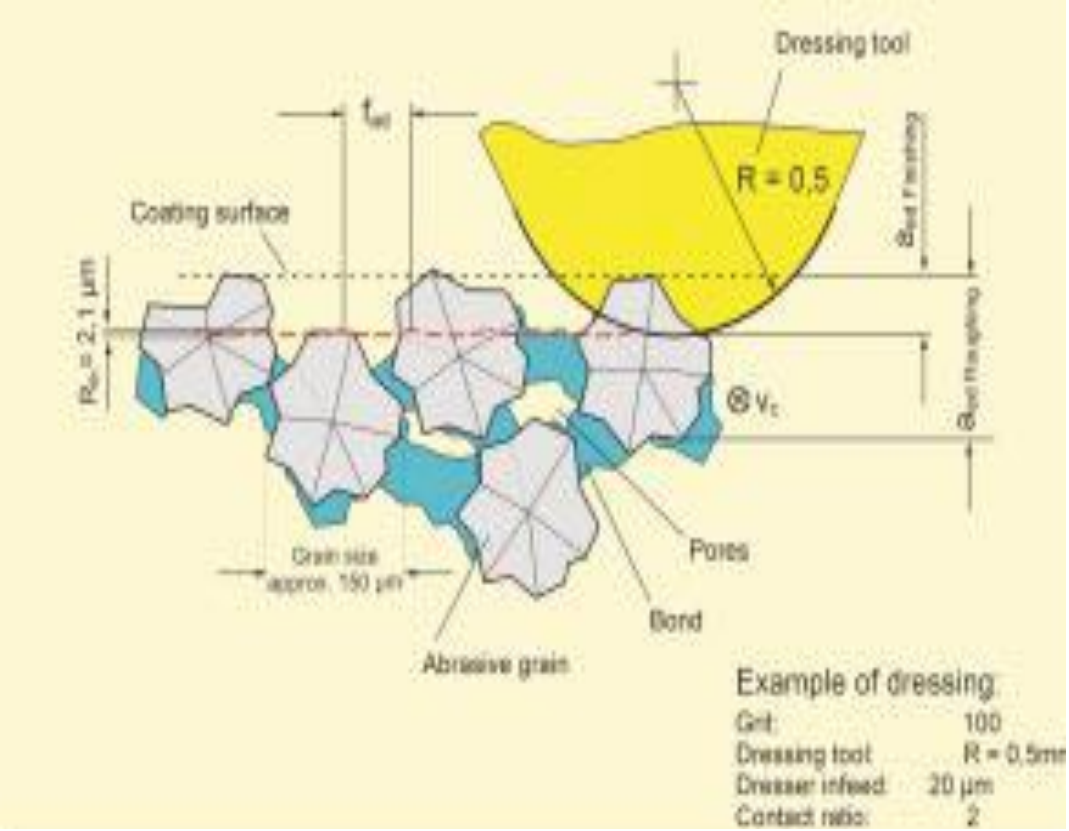


Figure 1.11:- Size relationships in form dressing

Therefore, the main influential factors in dressing are

Geometry and kinematics (i.e. contact ratio and speed ratio) and

Diamond coating

NOTES: A properly balanced and dressed wheel will enable the following to be achieved:

- Vibration will be reduced dramatically
- Grinding your tools will be easier
- You will get better edges
- Your grinding wheels will last longer

Table 1.5: Tools and Methods for Grinding Wheel Dressing and Truing

Designation	**Description**	**Application**
Rotating Hand Dressers	Freely rotating discs, either star-shaped with protruding points or discs with corrugated or twisted perimeter, supported in a fork-type handle, the lugs of which can lean on the tool rest of the grinding machine.	Preferred for bench- or floor-type grinding machines; also for use on heavy portable grinders (snagging grinders) where free-cutting proper ties of the grinding wheel are primarily sought and the accuracy of the trued profile is not critical.
Abrasive Sticks	Made of silicon carbide grains with a hard bond. Applied directly or supported in a handle. Less frequently abrasive sticks are also made of boron carbide.	Usually hand held and use limited to smaller-size wheels. Because it also shears the grains of the grinding wheel, or preshaping, prior to final dressing with, e.g., a diamond.
Abrasive Wheels (Rolls)	Silicon carbide grains in a hard vitrified bond are cemented on ball-bearing mounted spindles. Use either as hand tools with handles or rigidly held in a supporting member of the grinding machine. Generally freely rotating; also available with adjustable brake for diamond wheel dressing.	Preferred for large grinding wheels as a diamond saver, but also for improved control of the dressed surface characteristics. By skewing the abrasive dresser wheel by a few degrees out of parallel with the grinding wheel axis, the basic crushing action is supplemented with wiping and shearing, thus producing the desired degree of wheel surface smoothness.
Single-Point Diamonds	A diamond stone of selected size is mounted in a steel nib of	The most widely used tool for dressing and truing grinding wheels

	cylindrical shape with or without head, dimensioned to fit the truing spindle of specific grinding machines. Proper orientation and retainment of the diamond point in the setting is an important requirement.	in precision grinding. Permits precisely controlled dressing action by regulating infeed and cross feed rate of the truing spindle when the latter is guided by cams or templates for accurate form truing.
Single-Point Form Truing Diamonds	Selected diamonds having symmetrically located natural edges with precisely lapped diamond points, controlled cone angles and vertex radius, and the axis coinciding with that of the nib.	Used for truing operations requiring very accurately controlled, and often steeply inclined wheel profiles, such as are needed for thread and gear grinding, where one or more diamond points participate in generating the resulting wheel periphery form. Dependent on specially designed and made truing diamonds and nibs.
Cluster-Type Diamond Dresser	Several, usually seven, smaller diamond stones are mounted in spaced relationship across the working surface of the nib. In some tools, more than a single layer of such clusters is set at parallel levels in the matrix, the deeper positioned layer becoming active after the preceding layer has worn away.	Intended for straight-face dressing and permits the utilization of smaller, less expensive diamond stones. In use, the holder is canted at a 3° to 10° angle, bringing two to five points into contact with the wheel. The multiple-point contact permits faster cross feed rates during truing than may be used with single-point diamonds for generating a specific degree of wheel-face finish.
Impregnated	The operating surface consists	For the truing of wheel surfaces

Matrix-Type Diamond Dressers	of a layer of small, randomly distributed, yet rather uniformly spaced diamonds that are retained in a bond holding the points in an essentially common plane. Supplied either with straight or canted shaft, the latter being used to cancel the tilt of angular truing posts.	consisting of a single or several flat elements. The nib face should be held tangent to the grinding wheel periphery or parallel with a flat working surface. Offers economic advantages where technically applicable because of using less expensive diamond splinters presented in a manner permitting efficient utilization.
Form-Generating Truing Devices	Swiveling diamond holder post with adjustable pivot location, arm length, and swivel arc, mounted on angularly adjustable cross slides with controlled traverse movement, permits the generation of various straight and circular profile elements, kept in specific mutual locations.	Such devices are made in various degrees of complexity for the positionally controlled interrelation of several different profile elements. Limited to regular straight and circular sections, yet offers great flexibility of setup, very accurate adjustment, and unique versatility for handling a large variety of frequently changing profiles.

1.5.Selecting accessories to facilitate production.

Steady rest

Steady rests are very important in turning and are vital in cylindrical grinding for the suppression of vibration and for increasing control over surface finish and wheel wear.

Wheel forming and dressing attachment

Accurate plunge-cut grinding of forms and radii can be performed on a production basis on a cylindrical grinding machine by the use of a forming and dressing attachment of the projector dress type.

Internal grinding attachment

Internal grinding attachment for universal tool and cutter grinder to do internal grinding. Most internal grinding attachments come with several sizes of quills. Use the largest one possible for the hole being ground. The smaller quills tend to spring away from the work easily and produce tapers and irregularities.

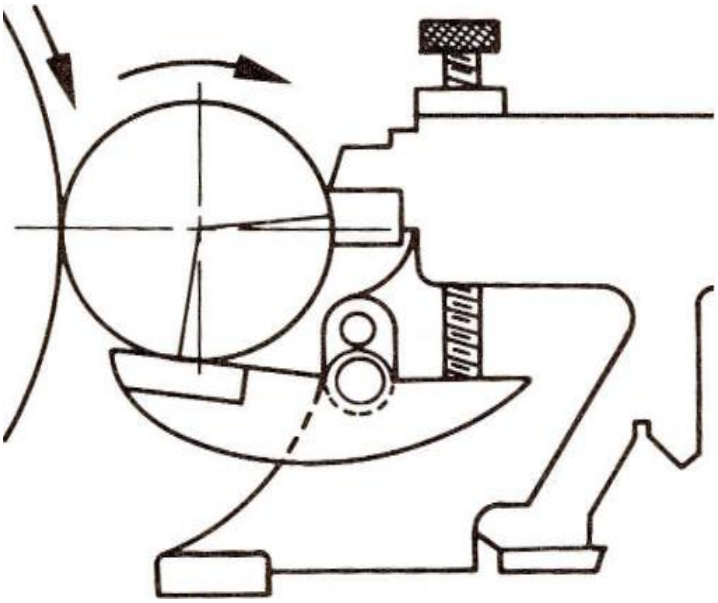


Figure 1.12፡- forming and dressing attachment

Self-check – 1	

Name…… ID…… Date…….

Part I :- Choose the best answer

Directions: Answer all the questions listed below. Examples may be necessary to aid some explanations/answers.

1.Unsafe work in terms of personal safety, work shop safety, and tools and equipment safety leads to

A. Accident B. Damage C. A & B

2.From the given choose which one is personal protective equipment.

A. Safety goggles B. Safety shoes C. Clothes D. gloves
E. ear protection F. all

3.If the grinding wheel properly balanced and dressedit enables to achive –

A. Reduce Vibration B. Grind better edge C .Longer life D. all

4.One is not an appropriate work holding device during grinding operation.

A. Magnetic chuck B. Universal vise C. Chuck and face plat D. Anvil

5.Which one not the selection of work holding device or system from the available resources?

A. Configuration of the machine tool ,B, Shape, size and weight of the blank , C, Kind of machining work to be done , D, Dimensional accuracy desired
E, None of the above

Part II: Matching

Direction- - Matching the column A to column B

column A	**column B**
1.Static motion	a. allowable deviation
2.Straight wheel	b. read &interpret chart drawing &blue print
3.Tolerance	c. Commonly found on pedestal or bench grinder
4.Primary responsibilities for grinding operation	d. rotation around its axis

Part III: Short Answer Questions

Directions - Give short answer to the following questions

1. List duties of grinding machine operator ?
2. Write down the appropriate work holding device during grinding operation?
3. Write down all the safety requirements for grinding machine?
4. Explain the difference between the static balance and dynamic balance ?

Unit Two: Perform intermediate grinding operations

This unit to provide you the necessary information regarding the following content coverage and topics:

- ✓ Set up and adjust grinding machines
  - Surface, cylindrical and eccentric grinding machines
- Performing grinding work procedures.
- Performing grinding operations
- Observing OHS measures and procedure.

This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Perform intermediate grinding operations
- Perform grinding work procedures.
- Perform grinding operations
- Observe OHS measures and procedure.

2.Perform intermediate grinding operations

2.1.Setting up and adjusting grinding machines

General grinding operations setup and its basic principles

Efficient grinding depends primarily upon the proper setup of the machine being used. If the machine is not securely mounted, vibration will result, causing the grinder to produce an irregular surface. Improper alignment affects grinding accuracy, and it is good practice to check the security and plumb of the machine every few months. It is advisable to place a strip of cushioning material under the mounting flanges, along with any necessary aligning shims, to help absorb vibration.

Setting up the machine:

- Inspect the mechanism to make sure nothing, aside from your stock, will touch it, bind, or get caught on the equipment.
- Keep the tool rest as close to the wheel but not touching it (gap should be between 1/8” and 1/4”).
- If the tool rest needs to be adjusted, unplug the machine first, and then adjust it.
- Where possible, always have the wheel rotation such that the grinding pressure is into the support finger.
- Choose a **finger** most suited for the job. There is no definite shape to use, but its length should be such that it gives adequate support to the work but is still free to flex to allow it to trip from one work to another.
- Fold back long sleeves up to the elbow.
- No rings, wrist watches, bracelets, or other jewelry that could get caught in the equipment.

Using the equipment:

- Make sure someone else knows that you are using the machine, press is available in case of an emergency.
- Be alert and cautious when using the grinding wheel.
- Keep hands and arms well clear of rotating wheel (if you have long hair, make sure it is tied back and will not touch the rotating wheel).
- Gently feed the stock into the wheel, do not force it. Move it side-to-side to avoid a hot spot on the wheel
- Maintain good balance (stand erect with both feet straight and slightly apart) while grinding your stock. Avoid leaning into the machine or stooping over the wheel.

When done:

- Perform these steps only after the equipment has been turned off, and the wheel has stopped turning.
- Clean up the shaving debris by using a brush or the shop vacuum to avoid potential splinters from the shavings.

If repairs are necessary

If odd noise, excessive vibration, or if an unsafe condition is observed:

- Turn machine off.
- Unplug machine and install "Plug Lockout" device (give key to the teacher or respective person) and install the "Tag out" label.
- Do not repair it yourself.
- Notify to your teacher, giving a description of what happened and your contact information.

Accident procedures:

- Administer proper First Aid; a kit is available in the specified work shop or room.
- Call or if using Cell Phone for emergency assistance.
- Seek medical help from Employee Health Services, or Student Health, or Hospital (no need to phone them before going).

NOTE: Please refer the specific operating procedures and machine set up from the manufacturer's manuals of surface, cylindrical and center less grinding machines found in your own work shop.

Laying out and grinding allowance

Laying out work: There are no special rules for laying out work for grinding operations. Most layout requirements will be dictated by the specific grinding machine to be used. In many cases, the workpiece will be turned on a lathe or machined in some other manner before grinding. The grinding is in preparation for the final finishing of the workpiece to the desired dimensions.

Grinding allowance: In planning work to be ground. the amount of metal to be removed should be based on the capabilities of the grinding machine. If the grinding machine is modern and in good condition, leave as much as l/32-inch or even more on large machine steel parts, but generally not more than l/64-inch on small machine parts.

Grinding speeds and feeds

Grinding speeds and feeds should be selected for the particular job. In grinding, the speed of the grinding wheel in surface feet per minute (SFPM) and the feed of the grinding wheel are as important as, and sometimes more important than, proper wheel selection. Occasionally, the grinder spindle should be checked with a tachometer to make sure it is running at its specified RPM. Too slow a speed will result in waste of abrasive, whereas an excessive speed will cause a hard grinding action and glaze the wheel, making the grinding inefficient.

The type of grinding wheel employed for a particular operation is one of the major considerations in the proper selection of cutting speed. The recommended cutting speed can then be determined by the wheel type, bond, and grade of hardness. The maximum wheel speed is determined by the ultimate bursting strength of the wheel and it depends on the abrasive used, grit size, bond, structure, grade, shape and size of the wheel. Its value is specified by the manufacturers which printed on the GW should never be exceeded.

WARNING: If a wheel is permitted to exceed the maximum safe speed, it may disintegrate and cause injury to the operator and damage to the grinding machine.

Safety: The grinding wheel should never be run at speeds in excess of manufacturer's recommendations, Usually, each grinding wheel has a tag attached to it which states the maximum safe operating speed.

Factors Governing Speed

The various factors governing the speed in surface feet per minute (SFPM) of a grinding wheel are as described below.

Material Being Ground

The material being ground will generally determine the grain, grade, structure, and bond of wheel to be selected. For example, if the wheel is too soft for the material being cut, an increase in speed will make the wheel act harder. Conversely, if the wheel is too hard, as lower speed will make the wheel act softer. Aluminum, brass and plastics can have poor to fair machinability characteristics for cylindrical grinding. Cast Iron and mild steel have very good characteristics for cylindrical grinding. Stainless steel is very difficult to grind due to its toughness and ability to work harden, but can be worked with the right grade of grinding wheels.

Condition of the Machine

Modern grinding machines and machines that are in good condition can safely turn a grinding wheel at speeds greater than machines that are older or in poor condition. Most grinding machines are equipped with spindle bearings designed for certain speeds which should not be exceeded. Poor quality will result from vibrations caused by inadequate rigidity or worn bearings

that are not in the best condition. High speeds will intensify these defects.

Work Speed for Surface Grinding

Surface grinding machines usually have fixed work speeds of approximately 50 surface feet per minute (SFPM) or have variable work speed ranges between 0 and 80 SFPM. As with cylindrical grinding, the higher work speeds mean that more material is being cut per surface foot of wheel rotation and therefore more wear is liable to occur on the wheel.

Work Speed for Cylindrical Grinding

In cylindrical grinding, it is difficult to recommend any work speeds since these are dependent upon whether the material is rigid enough to hold its shape, whether the diameter of the workpiece is large or small, and so forth. Listed below are areas to consider when performing cylindrical grinding:

The larger the diameter of the workpiece, the greater is its arc of contact with the wheel. The cutting speed suitable for one diameter of workpiece might be unsuitable for another.

The highest work speed that the machine and wheel will stand should be used for roughing.

The following cylindrical work speeds are only typical: steel shafts, 50 to 55 FPM; hard steel rolls, 80 to 85 FPM; chilled iron rolls, 80 to 200 FPM; cast iron pistons, 150 to 400 FPM; crankshaft bearings, 45 to 50 FPM; and crankshaft pins, 35 to 40 FPM.

Higher work speeds increase the cutting action of the wheel and may ‘indicate that a harder wheel and a smaller depth of cut be used to reduce wheel wear.

Wheel Size

In general practice, the wheel will be selected for the material to be cut. Both cutting speeds in surface feet per minute (SFPM) and rotational speed in RPM must be known to determine the size wheel to be used on a fixed-speed grinding machine.

To determine the grinding wheel size, use the following formula:

D = (12 x SFPM) / RPM

Where SFPM = Cutting speed of wheel (In surface feet per minute).

RPM = Revolutions per minute of wheel.

D = The calculated wheel diameter (in inches).

To obtain the cutting speed in SFPM when the wheel diameter and RPM are given, use the same formula in a modified form:

SFPM = (D x RPM) / 12

To obtain the rotational speed in RPM when the wheel diameter and desired cutting speed are known use the formula in another modified form:

RPM = (12 SFPM) / D

NOTE: As a grinding wheel wears down and as it is continually trued and dressed, the wheel diameter decreases, resulting in loss of cutting speed. As this occurs, it is necessary to increase the rotational speed of the wheel or replace the wheel to maintain efficiency in grinding.

Feeds

The **feed** of the grinding wheel will determine to a cetain extent the finish produced on the work and will vary for different types and shapes of grinding wheels.

The feed of the grinding wheel is the distance the wheel moves laterally across the workpiece for each revolution of the piece in cylindrical grinding or in each pass of the piece in surface grinding. The following methods are recommended for determine feeds:

The feed should be proportional to the width of wheel face and the finish desired. In general, The narrower the face of the wheel, the slower must be the traverse speed; the wider the wheel face the faster can be the traverse speed.

For roughing, the table should traverse about three quarter the wheel width per revolution or pass of the workpiece.

For an average finish, the wheel should traverse one-third to one-half the width of the wheel per revolution or pass of the workpiece.

In surface grinding with wheels less than 1 inch in width, the table traverse speed should be reduced about one-half.

Depth of Cut

Depth of cut (d) is called infeed and is defined as the distance between the machined and work surfaces. Methods for determining depth of cuts are recommended for determining feeds.

In roughing, the cut should be as deep as the grinding wheel will stand, without crowding or springing the work. The depth of cut also depends on the hardness of the material. In cylindrical grinding, in addition to these factors, the cut depends on the diameter of the work. In any case, experience is the best guide. Generally, a cut of 0.001 to 0.003 inch in depth is used, depending on the size and condition of the grinding machine.

For finishing, the depth of cut is always slight, generally from 0.0005 inch to as little as 0.00005 inch.

An indication of the depth of cut is given by the volume of sparks thrown off. Also, an uneven amount of sparks indicates that the workpiece or wheel is not concentric.

Safety:

- Never apply too heavy a cut. It only gives rise to rapid wheel wear, and overheating of the tooth being ground, which results in an inaccurate cutter. Depth of cut should be in the region of ,0005" to .001 " and allowed to "spark out" on each tooth.
- Avoid bumping work into wheel.

Cutting conditions in grinding

The **cutting velocity** (V) in grinding is very high. It is related to the rotational speed of the wheel by $V = \pi DN$

Where D is the wheel diameter, and N is the rotational speed of the grinding wheel.

cross-sectional area of cut, CSA

As the operation proceeds, the grinding wheel is fed laterally across the work surface on each pass by the workpart. The distance at which the wheel is fed is called a crossfeed. The crossfeed is actually the **width of cut** (w). The crossfeed multiplied by infeed determines the **cross-sectional area of cut**, CSA:

$$CSA = \text{crossfeed} \times \text{infeed} = wd$$

The cross-sectional area in grinding is relatively small compared to other traditional machining operations.

The workpart moves past the wheel at a certain linear or rotational velocity called a **feed** (V_w).

The **material removal rate**, mrr, is defined by $mrr = V_w CSA$

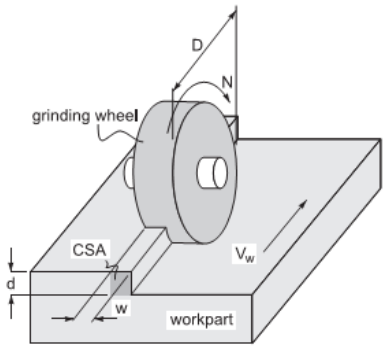


Figure 2.1. The geometry of surface grinding showing the cutting conditions

Cost elements of surface grinding:

- Time it takes to setup
- Time it takes to unload and load
- Time that the grinder is not in use
- Time it takes to grind the material
- Time it takes to change the tools
- The cost of tools/machinery
- Worker pay
- Sale price of finished product
- Paying for use of tools and equipment

Calculations

- **Time to grind** = Number of Grind Wheel Passes × the Length of the item to be ground ÷ the Feed rate of the material.
- **Number of Grind Wheel Passes** = the Width of ground item ÷ (width of grind wheel - the distance the grind wheel Overlaps previous runs) × thickness of the grind ÷ depth grind wheel removes per pass

2.1.1.Surface, cylindrical and eccentric grinding machines

Types of Grinding Machines

Based on the nature of the work-pieces ground, your grinding machines are broadly categorized into:

Surface Grinding Machines:- The primary use of a surface grinder is to remove material from a flat surface to finish the work piece to the correct size with a fine surface finish. They are also used for sharpening cutting tools, grinding off small flanges and also big cylinder blocks, machine base and many other items.

Your Surface Grinding Machines are required in every industry, be it an automobile industry, a consumer goods industry, or manufacturer of machine tools.

- Surface Grinding Machines
- Cylindrical and internal grinding machines are used for grinding cylindrical diameters and bores (internal diameter).
- Eccentric Centre less grinding machines come under the cylindrical grinding machine category.
- Tool and Cutter Grinding Machines:-are used for sharpening cutting tools.
-

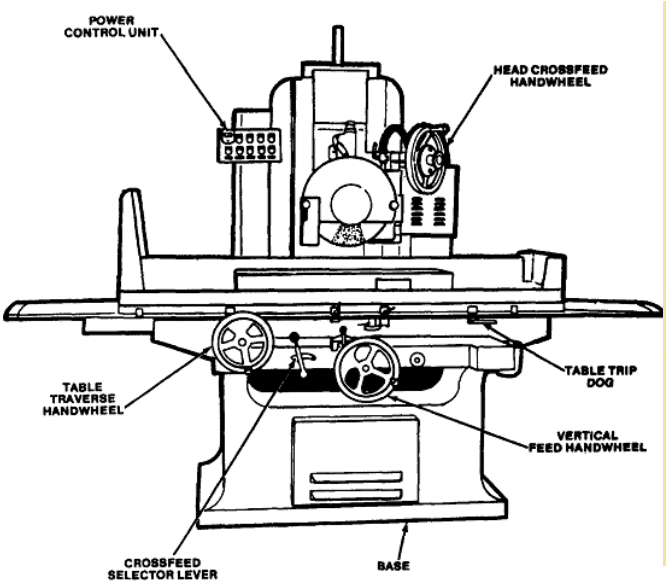
1.Surface Grinding Machines

These machines are used to finish flat surfaces. The most widely used types are:

A. Horizontal spindle

In this machine, the face of the wheel is used for grinding. The work is traversed under the wheel face gradually. Work is also fed laterally at each end of the stroke so that a required area may be ground.

Horizontal-spindle reciprocating-table grinders. Figure 2.2 illustrates a typical horizontal-spindle reciprocating-table grinder, on which a straight-shaped wheel (7) is commonly used. The bed (1) contains the drive mechanisms and the main table hydraulic cylinder. The table (2), actuated by the piston rod (3) of the hydraulic cylinder, reciprocates along ways on the bed to provide the longitudinal feed of the WP. T-slots are provided in the table surface for clamping WPs directly onto the table or for clamping grinding fixtures or a magnetic chuck. Nonmagnetic materials are held by a vise or special fixtures. The table stroke is set up by adjustable dogs (4). By means of a lever (5), the dogs reverse the table travel at the ends of the stroke. Push-button controls (6) start and stop the machine. A column (8) secured to the bed guides the vertical slide (9), which can be raised or lowered with the GW manually by the hand wheel (11). The vertical slide has horizontal ways to guide the wheel horizontally crosswise for traverse grinding. This slide is actuated by hand using a wheel (10) or by a hydraulic drive housed in the slide. The GW rotates at a constant speed; it is powered by a special built-in motor.



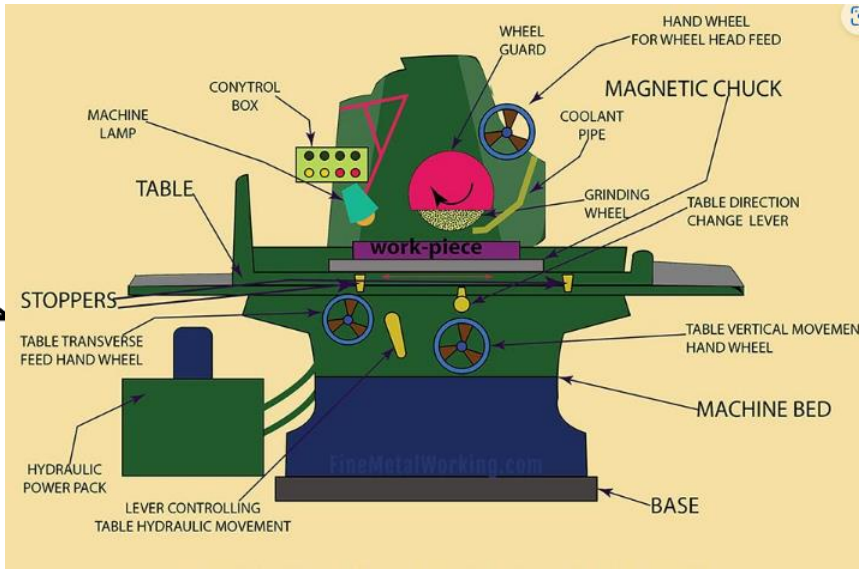


Figure 2.2 Horizontal-spindle reciprocating-table Surface grinder and Horizontal surface grinder

The principle of Horizontal-spindle reciprocating-table grinders

Reciprocating surface grinding machines generally have horizontal wheel spindles and mount straight or cylinder-type grinding abrasive wheels. The workpiece is supported (fastened) on a rectangular table which moves back and forth and reciprocates beneath the abrasive grinding wheel by hand or power feed. A magnetic chuck maybe used for fastening the workpiece to the table. This grinding machine has an internal pump and piping network for automatic application and recirculation of a coolant to the work piece and wheel. The grinding abrasive wheel, mounted to the horizontal spindle is straight and cuts on its circumferential surface only. Grinding wheel speeds are adjustable.

Operations that can be performed on horizontal-spindle reciprocating-table grinders are:

a. **Traverse grinding**, in which the table reciprocates longitudinally (v_w), and periodically fed laterally after each stroke at a rate f2 that is less than the GW width. The wheel is fed down to provide the infeed f1 after the entire surface has been ground (Figure 7a).

b. **Plunge grinding**, in which the wheel is fed perpendicular to the work surface at a rate f1, while the work reciprocates, as in grinding a groove (Figure 7b).

Creep-feed grinding (CFG)

Grinding has traditionally been associated with small rates of material removal and finishing operations. However, grinding can also be used for large-scale metal removal operations similar to milling, shaping, and planing. In **creep-feed grinding** (CFG), the depths of cut of up to 6 mm (d = 0.25 inches) are used along with low workpiece speed, which is fed very slowly past the wheel is accomplished in a single path. It is used for high rates of material removal. The wheels are mostly softer grade resin bonded with open structure to keep temperatures low and an improved surface finish up to 1.6 micrometers Rmax. Creep-feed grinding can be economical for specific applications, such as grinding cavities, grooves, etc.

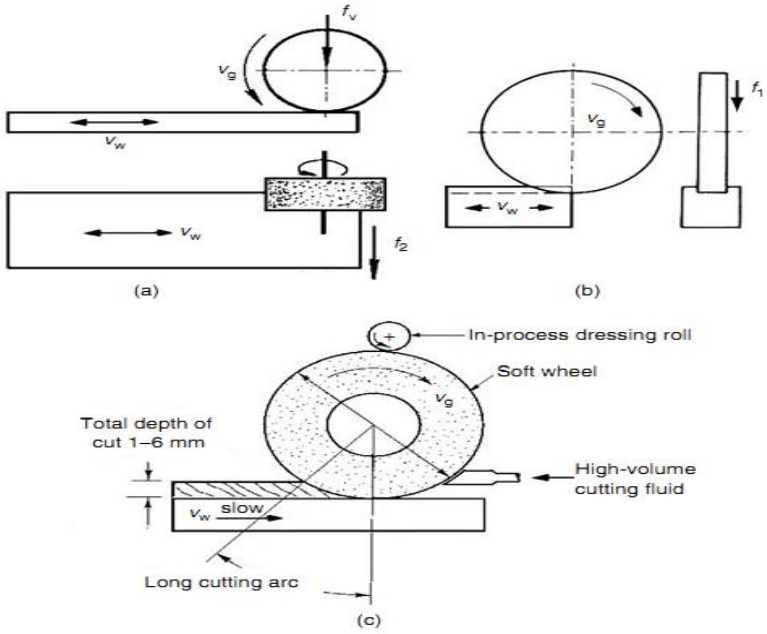


Figure 2.3. Operations performed on horizontal-spindle reciprocating table grinders. (a) Transverse grinding, (b) plunge grinding, (c) CFG.

Horizontal-spindle rotary-table grinders. The work is mounted on a revolving horizontal axis table which is at a speed v_w and the grinding wheel spindle is carried on a wheel slide which can be traversed across the work. The reciprocating cross-feed motion f1 is transmitted in these machines to either the GW or the table unit, the feed f2 is actuated per table revolution (Figure 8). this type of machine is generally used for precision grinding, and Concave or convex surfaces can be ground on individual parts by swiveling the table.

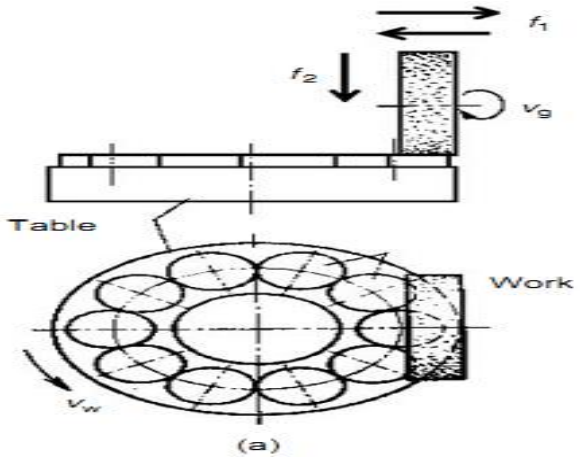


Figure 2.4. Operations performed on Horizontal spindle rotary-table grinders.

B. Vertical-spindle.

In this case, flat surfaces are produced with the side of wheel mounted on the vertical spindle. It is also called cup-grinding. The wheel head remains fixed and is fed down or up, until the work is finished. The principle is shown in Figure 9a and 9b.

1. Vertical-spindle reciprocating-table grinders. In these machines a cup, ring, or segmented wheel grinds the work over its full width using the end face of the wheel in one or several strokes of the table. The tool is fed down periodically at the infeed rate .

2. Vertical-spindle rotary-table grinders. These machines are similar to the previous type, except that the spindle is vertical. The configuration of these machines allows a number of pieces to be ground in one setup (Figure 9b).

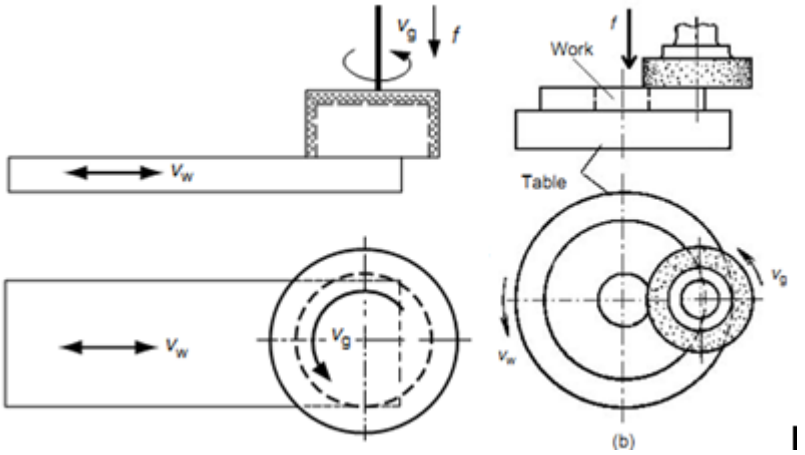


Figure 2.5. Operations performed on vertical-spindle grinders (a) reciprocating table and (b) rotary-table grinders

2.Cylindrical grinding machine

Cylindrical grinding is the practice of grinding cylindrical or conical workplaces by revolving the workpiece in contact with the grinding wheel. The main sub-classification of cylindrical grinders depends upon the method of supporting the work (between the centers, or centereless). In case of **centerless type,** the work is supported by the arrangement of the work rest, a regulating wheel and the grinding wheel itself. Both types use plain grinding wheels with the grinding face as the outside diameter.

Cylindrical grinding is also called center-type grinding and is used primarily for grinding cylindrical surfaces which may be parallel: tapered or fillets, grooves, shoulders and other formed surfaces of revolution. In case of **center type**, work between the centres, work is rotated independently and moved traversal as well. The speed of work can be varied to suit the

conditions. In this operation, the external or internal cylindrical surfaces of a workpiece are ground. Usually, “Cylindrical grinding” refers to external cylindrical grinding and the term “internal grinding” is used for internal cylindrical grinding. Another form of cylindrical grinding is conical grinding or grinding tapered workpieces.

In **external cylindrical** grinding the workpiece rotates and reciprocates along its axis, although for large and long workparts the grinding wheel reciprocates.

In **internal cylindrical** grinding, a small wheel grinds the inside diameter of the part. The workpiece is held in a rotating chuck in the headstock and the wheel rotates at very high rotational speed. In this operation, the workpiece rotates and the grinding wheel reciprocates. Tapered holes can be ground with the use of internal grinders that can swivel on the horizontal.

In **taper grinding** machine, the workpiece is supported between centers. The headstock wheel head, and tailstock (both of which (nay be swiveling or non-swiveling type) are mounted on a swivel table which itself is mounted on a sliding table that can move to and for in the bed guide ways. A special feature of these is to grind multi-diameter shafts and control then concentricity.

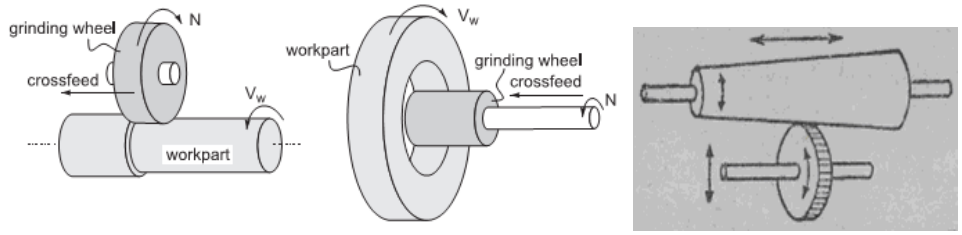


Figure 2.6. Types of Cylindrical grinding operations: external, internal, and taper (from left to right)

External Cylindrical Grinding Machines and Related Operations

This type of machine is mainly used for grinding external cylindrical surfaces, which may be parallel or tapered, or filets, grooves, shoulders, or other formed surfaces of revolution. Typical applications include crankshaft bearings, spindles, shafts, pins, and rolls for rolling mills. The workpiece is mounted and rotated by a workpiece holder, also known as a grinding dog or center driver. Both the tool and the workpiece are rotated by separate motors and at different speeds. The axes of rotation tool can be adjusted to produce a variety of shapes. The workpiece and wheel are set to rotate in opposite directions at the point of contact. The rotating cylindrical WP reciprocates laterally along its axis. However, in machines used for long shafts, the GW reciprocates. The latter design configuration is called a roll grinder and is capable of grinding

heavy rolls as large as 1.8 m in diameter.

The depth of cut is controlled by feeding wheel into the work. The depth of Cut for roughing cut is normally 005 mm, but for finishing cuts, the feed is reduced to 0005 mm. In selecting the amount of infeed, consideration must be given to the size, rigidity of work, the finish desired and whether coolant is used or not

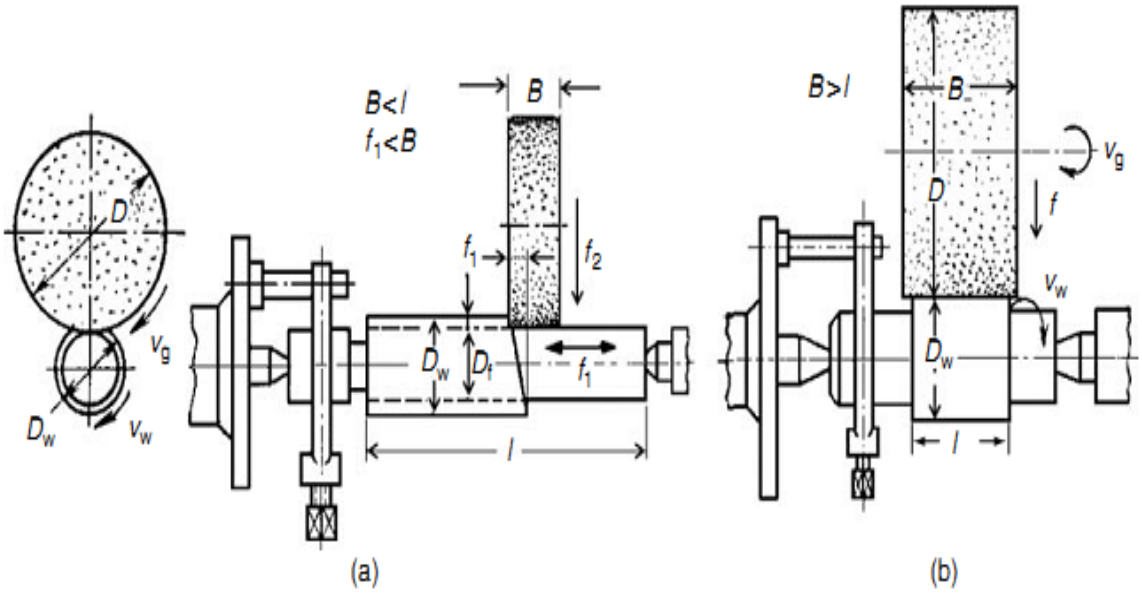


Figure 2.7. External cylindrical grinding operations.

Working principle of center-type Cylindrical grinding

- Three types of feed motion are possible according to the direction of feed motion,
- traverse **feed** grinding (also through feed grinding, cross-feeding) in which the relative feed motion is parallel to the spindle axis of rotation,
- **plunge grinding** in which the grinding wheel is fed radially into the work piece, and
- a **combination of traverse and plunge** grinding in which the grinding wheel is fed at 45^0 to grind simultaneously the cylindrical part of the workpiece and the adjacent face. This method provides a precise perpendicular mutual position of both surfaces.

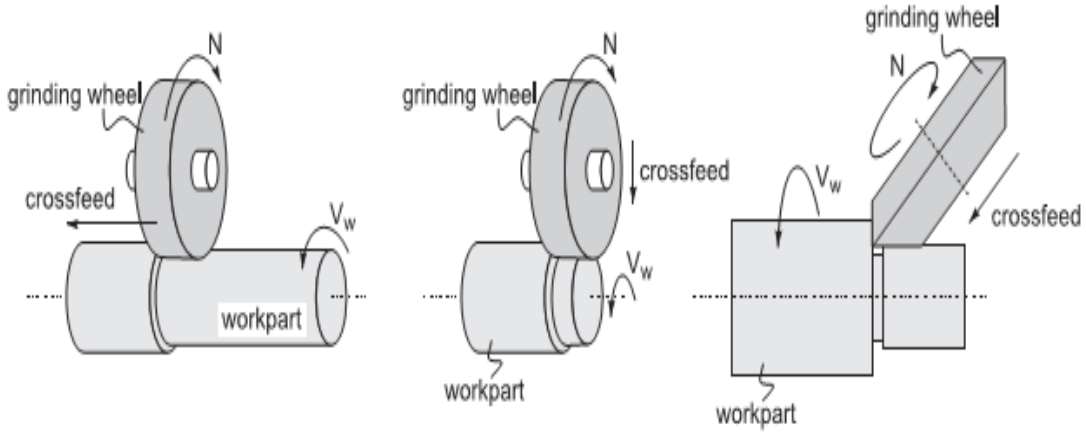


Figure 2.8: Three types of cylindrical grinding: (From left to right) traverse feed grinding, plunge grinding, a combination of both previous types.

1. **Universal cylindrical grinding machines**:

Universal-type grinders make it possible to swivel both the work piece and the grinding wheel axis can be swivelled around a horizontal plane by work head and wheel head (headstock). It is possible to grind steep tapered surfaces and this machine can be used for all types of cylindrical grinding i.e. internal, face and surface grinding by using some attachments, it is also possible to carry out plunge cylindrical grinding, taper plunge grinding. The various operations are possible on a universal cylindrical grinding machine. Owing to their versatility, universal cylindrical grinders are best suited for tool room applications.

Plain-type grinders

This type is basically designed for heavy repetitive single work. It is not very versatile, and is used for grinding tapers with small included angles, in which the worktable can be swiveled through an angle of only ±6°.

Straight plunge type

These are basically high volume production machines. The wheel is plunged into the work at a predetermined feed rate and is withdrawn after correct size is produced.

Angular wheel slide plunge type

Angular-wheel slide plunge cut type machine is used to finish shoulder surfaces at right angles correctly in a single operation by an angular wheel.

Conical Grinding

Most conical grinding is performed in the same manner as plain cylindrical grinding. Once the grinding machine is set up, the table is swiveled until the correct taper per inch is obtained. Steep conical tapers are normally ground by swiveling the headstock to the angle of taper. Whichever method is used, the axis of the grinding wheel must be exactly at center height with the axis of the work.

Form grinding

Form grinding is a specialized type of cylindrical grinding where the grinding wheel has the exact shape of the final product. The grinding wheel does not transverse the workpiece.

Chucking Type Cylindrical Grinders.

These are used for grinding external surfaces of short work-pieces having no centre holes and no convenient surface for driving.

2.2.Performing grinding work procedures.

Before starting the operation of grinder the **machine parts** such as machine guard (specially wheel guard) coolant pump, coolant hose and coolant tanker and dust extractor should be checked properly. Whenever practical, a **coolant** should be applied to the point of contact of the wheel and the workpiece to keep the wheel and workpiece cool, to wash away the loose abrasive, and to produce a better finish.

Rules and procedures in grinding operation

Any unsafe practice in grinding can be hazardous for operation and deserves careful attention. Various important aspects in this respect are:

Wheel selection. The grinding wheel for any grinding operation should be carefully chosen and the workpiece set up properly in the grinding machine.

Wheel inspection. Before mounting the wheel, it should be checked for damage in transit, cracks and other defects. Ringing test is good enough for vitrified bond wheels. Sound wheels, when tapped lightly at 45 from the vertical line with a plastic hammer (non-metallic object) and listen for a brief ring sound like a clear metallic ring. If there is a ring, the wheel is most likely OK, if it sounds dull/dead, do not use the wheel because the cracked wheel will not ring.

a. **Wheel storage.** When not used, the wheels should be stored in a dry room and placed on their edges in racks.
b. **Mounting of grinding wheels**. The wheel should be correctly mounted in the spindle and

enclosed by a guard. Wheel bore should not be a tight fit on the sleeve.

c. **Wheel guards**. These should always be used during grinding, and periodically adjusted to compensate for wheel wear. Always fit wheel guard securely in position closely over grinding wheel before starting machine, and rotate spindle by hand before running on power to ensure wheels are free to rotate and are not rubbing guards, fingers or fixtures.
d. **Dust collection and health precaution**. When grinding dry, provision for extracting grinding dust should be made. Protective covers of machine should never be removed while machine is in use. Operator should wear safety devices to protect his eyes and body from flying abrasive particles and dust.
e. **Wheel operation**. Adequate **power** is essential in grinding machines. If power is not adequate then wheels will slow down and develop flat spots, making the wheel to run out-of-balance.

Rules and procedures in grinding operation

Any unsafe practice in grinding can be hazardous for operation and deserves careful attention. Various important aspects in this respect are:

f. **Wheel selection**. The grinding wheel for any grinding operation should be carefully chosen and the workpiece set up properly in the grinding machine.
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h. **Wheel storage.** When not used, the wheels should be stored in a dry room and placed on their edges in racks.
i. **Mounting of grinding wheels**. The wheel should be correctly mounted in the spindle and enclosed by a guard. Wheel bore should not be a tight fit on the sleeve.
j. **Wheel guards**. These should always be used during grinding, and periodically adjusted to compensate for wheel wear. Always fit wheel guard securely in position closely over grinding wheel before starting machine, and rotate spindle by hand before running on power to ensure wheels are free to rotate and are not rubbing guards, fingers or fixtures.
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l. **Wheel operation**. Adequate **power** is essential in grinding machines. If power is not adequate then wheels will slow down and develop flat spots, making the wheel to run out-of-balance.

Setting up the machine:

- Inspect the mechanism to make sure nothing, aside from your stock, will touch it, bind, or get caught on the equipment.
- Keep the tool rest as close to the wheel but not touching it (gap should be between 1/8" and 1/4").
- If the tool rest needs to be adjusted, unplug the machine first, and then adjust it.
- Where possible, always have the wheel rotation such that the grinding pressure is into the support finger.
- Choose a **finger** most suited for the job. There is no definite shape to use, but its length should be such that it gives adequate support to the work but is still free to flex to allow it to trip from one work to another.
- Fold back long sleeves up to the elbow.
- No rings, wrist watches, bracelets, or other jewelry that could get caught in the equipment.

Using the equipment:

- Make sure someone else knows that you are using the machine, press is available in case of an emergency.
- Be alert and cautious when using the grinding wheel.
- Keep hands and arms well clear of rotating wheel (if you have long hair, make sure it is tied back and will not touch the rotating wheel).
- Gently feed the stock into the wheel, do not force it. Move it side-to-side to avoid a hot spot on the wheel
- Maintain good balance (stand erect with both feet straight and slightly apart) while grinding your stock. Avoid leaning into the machine or stooping over the wheel.

When done:

- Perform these steps only after the equipment has been turned off, and the wheel has stopped turning.
- Clean up the shaving debris by using a brush or the shop vacuum to avoid potential splinters from the shavings.

If repairs are necessary

If odd noise, excessive vibration, or if an unsafe condition is observed:

- Turn machine off.
- Unplug machine and install "Plug Lockout" device (give key to the teacher or respective person) and install the "Tag out" label.
- Do not repair it yourself.

- Notify to your teacher, giving a description of what happened and your contact information.

Accident procedures:

- Administer proper First Aid; a kit is available in the specified work shop or room.
- Call or if using Cell Phone for emergency assistance.
- Seek medical help from Employee Health Services, or Student Health, or Hospital (no need to phone them before going).

NOTE: Please refer the specific operating procedures and machine set up from the manufacturer's manuals of surface, cylindrical and center less grinding machines found in your own work shop.

Laying out and grinding allowance

Laying out work: There are no special rules for laying out work for grinding operations. Most layout requirements will be dictated by the specific grinding machine to be used. In many cases, the workpiece will be turned on a lathe or machined in some other manner before grinding. The grinding is in preparation for the final finishing of the workpiece to the desired dimensions.

Grinding allowance: In planning work to be ground. the amount of metal to be removed should be based on the capabilities of the grinding machine. If the grinding machine is modern and in good condition, leave as much as l/32-inch or even more on large machine steel parts, but generally not more than l/64-inch on small machine parts.

Grinding speeds and feeds

Grinding speeds and feeds should be selected for the particular job. In grinding, the speed of the grinding wheel in surface feet per minute (SFPM) and the feed of the grinding wheel are as important as, and sometimes more important than, proper wheel selection. Occasionally, the grinder spindle should be checked with a tachometer to make sure it is running at its specified RPM. Too slow a speed will result in waste of abrasive, whereas an excessive speed will cause a hard grinding action and glaze the wheel, making the grinding inefficient.

The type of grinding wheel employed for a particular operation is one of the major considerations in the proper selection of cutting speed. The recommended cutting speed can then be determined by the wheel type, bond, and grade of hardness. The maximum wheel speed is determined by the ultimate bursting strength of the wheel and it depends on the abrasive used, grit size, bond, structure, grade, shape and size of the wheel. Its value is specified by the

manufacturers which printed on the GW should never be exceeded.

WARNING: If a wheel is permitted to exceed the maximum safe speed, it may disintegrate and cause injury to the operator and damage to the grinding machine.

Safety: The grinding wheel should never be run at speeds in excess of manufacturer's recommendations, Usually, each grinding wheel has a tag attached to it which states the maximum safe operating speed.

Factors Governing Speed

The various factors governing the speed in surface feet per minute (SFPM) of a grinding wheel are as described below.

Material Being Ground

The material being ground will generally determine the grain, grade, structure, and bond of wheel to be selected. For example, if the wheel is too soft for the material being cut, an increase in speed will make the wheel act harder. Conversely, if the wheel is too hard, as lower speed will make the wheel act softer. Aluminum, brass and plastics can have poor to fair machinability characteristics for cylindrical grinding. Cast Iron and mild steel have very good characteristics for cylindrical grinding. Stainless steel is very difficult to grind due to its toughness and ability to work harden, but can be worked with the right grade of grinding wheels.

Condition of the Machine

Modern grinding machines and machines that are in good condition can safely turn a grinding wheel at speeds greater than machines that are older or in poor condition. Most grinding machines are equipped with spindle bearings designed for certain speeds which should not be exceeded. Poor quality will result from vibrations caused by inadequate rigidity or worn bearings that are not in the best condition. High speeds will intensify these defects.

Work Speed for Surface Grinding

Surface grinding machines usually have fixed work speeds of approximately 50 surface feet per minute (SFPM) or have variable work speed ranges between 0 and 80 SFPM. As with cylindrical grinding, the higher work speeds mean that more material is being cut per surface foot of wheel rotation and therefore more wear is liable to occur on the wheel.

Safety:

- Never apply too heavy a cut. It only gives rise to rapid wheel wear, and overheating of the tooth being ground, which results in an inaccurate cutter. Depth of cut should be in the region of ,0005" to .001 " and allowed to "spark out" on each tooth.
- Avoid bumping work into wheel.

Cutting conditions in grinding

The **cutting velocity** (V) in grinding is very high. It is related to the rotational speed of the wheel by $V = \pi DN$

Where D is the wheel diameter, and N is the rotational speed of the grinding wheel.

cross-sectional area of cut, CSA

As the operation proceeds, the grinding wheel is fed laterally across the work surface on each pass by the workpart. The distance at which the wheel is fed is called a crossfeed. The crossfeed is actually the **width of cut** (w). The crossfeed multiplied by infeed determines the **cross-sectional area of cut**, CSA:

$$CSA = \text{crossfeed} \times \text{infeed} = wd$$

The cross-sectional area in grinding is relatively small compared to other traditional machining operations.

The workpart moves past the wheel at a certain linear or rotational velocity called a **feed** (V_w).

The **material removal rate**, mrr, is defined by $mrr = V_w CSA$

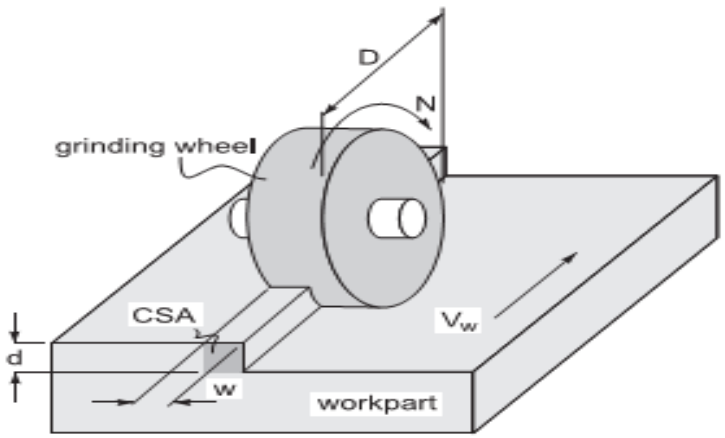


Figure 2.9. The geometry of surface grinding showing the cutting conditions

Cost elements of surface grinding:

- Time it takes to setup
- Time it takes to unload and load
- Time that the grinder is not in use
- Time it takes to grind the material

- Time it takes to change the tools
- The cost of tools/machinery
- Worker pay
- Sale price of finished product
- Paying for use of tools and equipment

Calculations

- **Time to grind** = Number of Grind Wheel Passes × the Length of the item to be ground ÷ the Feed rate of the material.
- **Number of Grind Wheel Passes** = the Width of ground item ÷ (width of grind wheel - the distance the grind wheel Overlaps previous runs) × thickness of the grind ÷ depth grind wheel removes per pass

2.3.Performing grinding operations

Applications of Grinding wheel:

The main application of grinding wheel is to remove the material in the form of tiny chips and make the surafce smooth as much as possible.

The Grinding machine is a surface finishing Machine in which Grinding wheels are fixed(This is our tool) for surface finish.

Even the grinding wheel are different type as discussed above and there uses for the different work piece.

Grinding wheel bond types:

A bond is an abrasive material used to held abrasive particles together. The bonding material does not cut during the grinding operations.

Its main function is to hold the grains together with varying degrees of strength.

The different standard grinding wheel bonds are vitrified, resinoid, silicate, shellac, rubber, and metallic.

Factors affecting the selection of Grinding wheels:

Proper grinding wheel selection is essential to ensure that the required

Part quality,

Production rate, and

The overall cost per part is achieved.

It is normally depends upon several terms like:

The type of grinding operation we performed

Grinding machine condition

Requirement of surface finishing

Shape and size of a work piece

Work piece material.

Difference between cutting wheel and Grinding Wheel

In the grinding wheel, there is term Abrasive which we studied, it provides surface finishing helps to get good surface finish of the work piece and also provides good luster.

Table .2.1 Difference between cutting wheel and Grinding Wheel

Grinding Wheel	Cutting Wheel
The grinding wheel has good strength which avoids cutting improper shape and size.	The normal cutting tool doesn't have abrasive. So it will not provide better finishing accuracy as grinding wheel provides.
The chances of wear and tear are high in cutting wheel	A grinding wheel having low chances of wear and tear.
Price of a grinding wheel is more	The price of the cutting wheel is less than grinding wheel.

2.4.Observing OHS measures and procedure.

Safety is the safe of being free from danger. Occupational health and safety (OHS) information is discussed and shared with colleagues. As always we should be aware of safety requirements and attempt to observe safety rules in order to eliminate serious injury to ourselves or others. Personnel working with machines must be aware of the risks involved and follow safe work

practices. Basic cause of accidents is faulty attitude toward safety, Failure to recognize danger and Emotion. Machine operator should follow safety precautions required in terms of personal safety, work shop safety, and tools and equipment safety to avoid injuries.

Pre-operational safety checks

1. Check workspaces and walkways to ensure no slip/trip hazards are present.
2. Ensure all guards and safety shields are in position before starting the grinder.
3. Ensure that the wheels do not touch the work rest and that the gap between wheel and rest is no greater than 1.5mm.
4. Check grinding wheels for cracks (Ring Test) before mounting
5. Check that wheels are running true and are not glazed or loaded.
6. Locate and ensure you are familiar with the operation of the ON/OFF starter.
7. Faulty equipment must not be used. Immediately report any suspect machine.
8. On bench grinders, adjust tool rest 1/16 to 1/8 inch from the wheel

Operational safety checks

1. Wear goggles for all grinding machine operations
2. Stand to the side of the wheels when starting up.
3. Let the wheels gain maximum speed before starting to grind.
4. Do not grind on the side of the wheel.
5. Small objects must not be held by hand.
6. Never adjust the work piece or work mounting devices when the machine is operating
7. Never leave the machine running unattended.
8. Do not bend down near the machine whilst it is running.
9. Never force the work piece against a wheel.
10. Do not exceed recommended depth of cut for the grinding wheel or machine.
11. Slowly move the work piece across the face of the wheel in a uniform manner.
12. Coolant spilt on the floor should be immediately absorbed.
13. Use proper wheel guards on all grinding machines.

Housekeeping

1. Switch off the machine.
2. Leave the machine in a safe, clean and tidy state.

Potential hazards

1. Hot Metal
2. Sparks
3. Noise

4. Sharp edges and burns
5. Entanglement
6. Wheels ‘run on’ after switching off
7. Eye injuries

Forbidden

1. Work piece must never be held with gloves, cloth, apron or pliers
2. Grinding nonferrous metals

Self-check – 2	

Part I: Part I:- True or False

Directions: Say True or False for the given question accordingly

1.There are two common methods of aligning
2.the accessories of Cylindrical grinding machines are similar to the accessories of surface grinding machines
3.Sparks are one of the the common causes of grinding accidents
4. Surface grinding machines are used to finish flat surfaces

Part II:- Short Answer Questions

Directions: Answer all the questions listed below.

1. List duties of grinding machine operator
2. Write down all the safety requirements for grinding machine.
3. Write three examples of Hazards parts of machines?
4. List duties of operator while setting up working
5. List duties of operator while setting up working
6. Write down all the safety requirements for grinding machine.
7. What is the main purpose of grinding machines?
8. Write down some of the grinding machines.
9. What is the main standard equipment of grinding machines?
10. What are the common causes of grinding accidents?

Part III

Directions: Fill in the blank

1.Essential element of a working drawing is _____

2.The first activities to make desired shape and size a product or project is to do _____

Part VI :-Explain.

Directions: Explain the following question correctly

1.If the sequence of markings on a typical wheel listed as **51A36L55V23,** what is the meaning of each letter and number in this markings indicate.

2. A soft-grade grinding wheel is generally recommended for hard materials whey explain?

Unit Three: Quality assure components in conformance to specifications

This unit to provide you the necessary information regarding the following content coverage and topics:

Checking components
Determining the required grade of tolerance

This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

Check components
Determine the required grade of tolerance

.

3.Quality assure components in conformance to specifications

The main motive of manufacturing is to process engineering materials and produce desired and useful components or products to the specified shape, size and finish. The **specifications** for the shapes, sizes and finishes on the products are furnished by the manufacturing operations through specified process plan using part drawings or manufacturing drawing.

These specifications basically termed as called **quality characteristics**. The quality of manufactured product always depends upon the process capability of controlling manufacturing functions which may lead to a certain amount of variation as a result of chance and some cause. Also some chance or cause is inherent in any particular scheme of production and inspection. The reasons for variation outside this stable system should be discovered and corrected to minimize wastage and finally to improve quality.

3.1.Checking components

Inspection or checking of components or products with required specifications is very minutely related with quality control. The working **drawing** requirement is an effective way of preventing quality problems. It is generally an accepted fact that no two things can ever be exactly same. It also holds true with manufactured parts. Therefore, certain **variations or deviations** in dimensions and other product specifications are **accepted**. However, only few produced articles or parts may be **rejected** if the deviations go beyond the specified quality standards. Therefore, it becomes essential to detect errors so that the manufacturing of faulty product does not go uncorrected.

Deviations is the differences of measurement from the given tolerances and the differences of measurement between each value in from working drawing's dimensions.

Policies and procedures are designed to influence and determine all major decisions and actions, and all activities take place within the boundaries set by them. **Procedures** are the specific methods employed to express policies in action in day-to-day operations of the organization.

Definitions of conformance

Conformance is usually defined as testing to see if an implementation successfully meets the requirements of a standard or specification. There are many types of testing including testing for

performance, strength, surface finish, shape and dimensions. Some common **methods** are visual; using measuring tools and equipment. Although conformance testing may include some of these kinds of tests, it has one **fundamental difference** of the requirements or criteria for conformance must be specified in the **standard or specification**. This is usually in a conformance clause or conformance statement, but sometimes some of the criteria can be found in the body of the specification. Some standards have subsequent documentation for the test methodology and assertions to be tested. If the criteria or requirements for conformance are not specified, there can be no conformance testing.

A non-conformance report must include at a minimum of the following information:

- What is the main reason for the Non-Conformance Report or what went wrong?
- Why the work doesn't meet the requirement
- What can be done to prevent the problem from happening again?
- Explanation of corrective action taken/to be taken

Inspection

Inspection is an organized examination or formal evaluation exercise. The philosophy of **inspection** is only preventive and not remedial. In other words, the inspection of products is measuring or checking its quality in terms geometrical tolerances of other specified feature of needed design. Generally, there are three basic areas of inspection namely receiving inspection, in-process inspection and final inspection.

In the **receiving inspection**, inspections are performed on all incoming materials and purchased parts. In the **in-process inspection** the products are inspected as they are in processed in stages from starting station to finished station. In the **final inspection**, all finished products or parts are inspected finally prior to delivering them to the customer.

Inspection **in manufacturing** includes measuring, examining, testing, or gauging one or more characteristics of a product or process and comparing the results with specified requirements and standards to determine whether the requirements are met for each characteristic or in line with the targets.

The main purpose of **product inspection** is to ensure that the products sent into the market comply with the set standard for quality. In other words, it is to ensure that the product ready for

sale is perfect and free of defects. Product inspection is conducted at various stages of the manufacturing process, prior to its dispatch; to secure production, verify product quality, safeguard the quality of your product and protect brand image.

Common examples of **inspection by measurement or gauging** include using a caliper or micrometer to determine if a dimension of a manufactured part is within the dimensional tolerance specified in a drawing for that part, and is thus acceptable for use. **Measurement instruments** used to certify manufacturing conformity should be considered early in the design of products. **Visual inspection** is also the most widely used method for detecting and examining variety of surface flaws that are particularly important because of their relationship to failure mechanisms.

3.2.Determining the required grade of tolerance

Grade of Grinding wheel:

The grade refers to the hardness or strength with which the bond holds the abrasive grains of a grinding wheel in a place.

The Grade is indicated by the English alphabet **A to Z.**

A denotes Softest and **Z** denotes Hardest Grade.

The different grade of the grinding wheel as follows:

Table 3.1 The different grade of the grinding wheel

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**

Structure of Grinding wheel:

The structure refers to the spacing between the abrasive grains in the grinding wheel.

It is denoted by the number of cutting edges per unit area of wheel face and size of void spaces between grains.

If there is a large number of cutting edges per unit area, the structure is called Dense structure otherwise it is called an open structure.

It is numbered 1 to 16—the higher the number the “more open” the structure (wider grain spacing). The use of this number is optional.

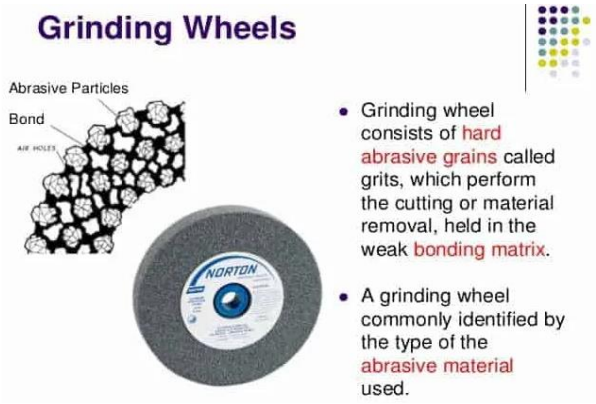


Figure 3.2. Grine structure of grinding wheel

The different structure of the grinding wheel is shown in the following table

Table.3.2 The different structure of the grinding wheel

Dense	**1, 2, 3, 4, 5, 6, 7, 8**
Open	**9, 10, 11, 12, 13, 14, 15,16**

Specification or Nomenclature of Grinding wheel:

The Indian standard marking system (IS: SS1-1954) has been used to indicate the various characteristics of a grinding wheel.

Each marking consists of 6 symbols, denoting the following characteristics:

1. Abrasive
2. Grain Size
3. Grade
4. Structure
5. Bond type
6. Manufactures record **A 30 I 4 V 17**

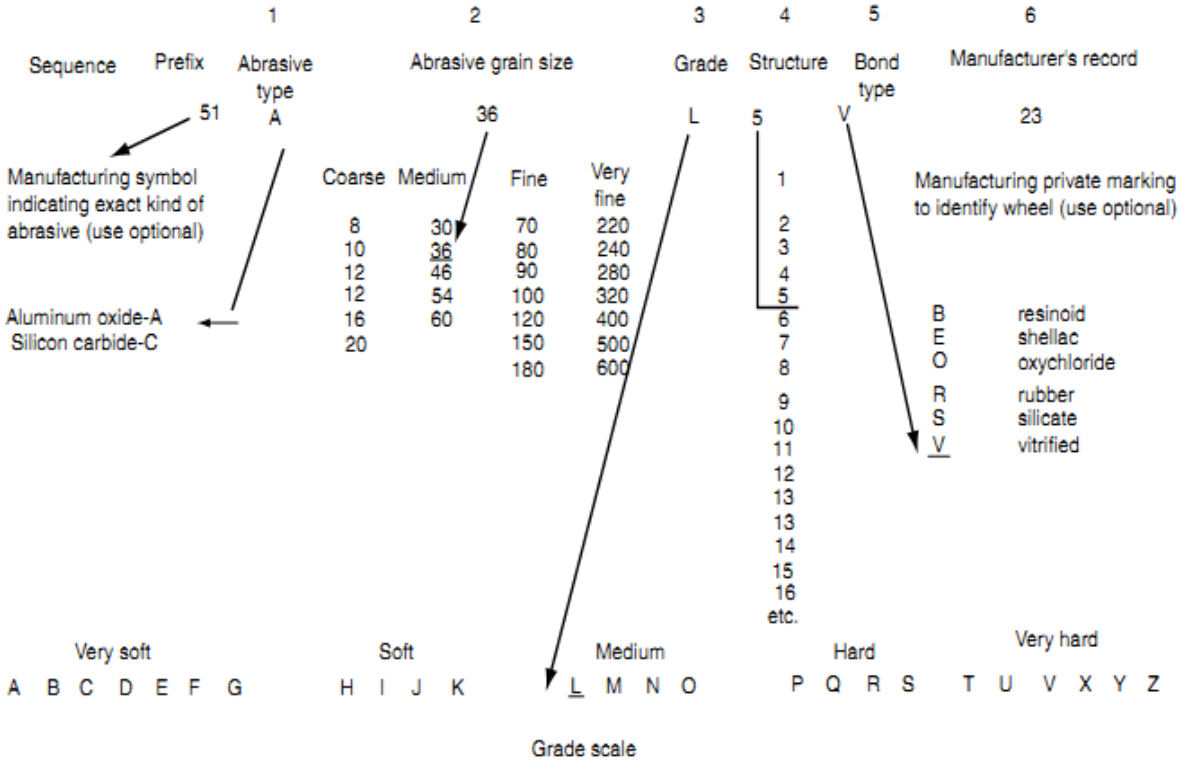


Figure 3.1. Standard system of marking grinding wheel

Table .3.3-Specification or Nomenclature of Grinding wheel:

W (Prefix) = *Manufacture abrasive type symbols.* ***17 (Suffix) =*** Manufacturing abrasive type symbol									
Manufactures record	***A***	***A (Abrasive)***	*[A = Aluminum Oxide],*	*[C = Silicon Carbide],*	*[D = Diamond]*				
	30								
	I	**(Grain Size) = 4 Types of grain Size.**	**1**	Coarse	**10,12,14,16,20,24**				
			2	Medium	**30,36,46,54,60**				
			3	Fine	**80,100,120,150,180**				
			4	Very fine	**220,240,280,320,400,500,600**				
	4	***I (Grade) = Grade categories in to 3 parts***	**1**	**Soft**	**A,B,C,D,E,F,G,H**				
			2	**Medium**	**I,J,K,L,M,N,O,P**				
			3	**Hard**	**Q,R,S,T,U,V,W,X,Y,Z**				
	V	***4(Structure) Structure categories in 2 parts.***	**1**	Dense	**1,2,3,4,5,6,7,8**				
			2	Open	**9,10,11,12,13,14,15**				
	17	***V (Bond Type) Vertified Bond***	**six stype**	**V**	**B**	**R**	**E**	**S**	**O**
				vertified	Resionid	Rubber	Shellac	Silicon	Oxychloride

Bond indicates the type of material that holds the abrasive grains (wheel) together. Eight types are used:

- B = Resinoid
- BF = Resinoid reinforced
- E Shellac
- 0 = Oxychioride
- R = Rubber
- RF = Rubber reinforced
- S=Silicate
- V = Vitrified

Wheel grade:- is the strength of the bond holding the wheel together ranging from A (soft) to Z (hard). An additional number or letter(s) is sometimes used as the manufacturer's private marking to identify the grinding wheel.

Grain size:- is indicated by a number, usually from 8 (coarse) to 600 (very fine).

Abrasive grains are selected according to the mesh of a sieve through which they are sorted. For example, grain number 40 indicates that the abrasive grain passes through a sieve having approximately 40 meshes to the linear inch.

The different grain of the grinding wheel as follows:

Table .3.4 .The different Grain of the grinding wheel

Types of Grit	**Grit or Grain Size**
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

Compulsory Elements.

(I) ***Abrasive,***

These-are-denoted-by:

A — for MO, C — for SiC, WA — for white MO, GC — for green grit SIC.

(2) ***Grain size*** It is denoted by grit number. The various numbers for different types of grain size are-given-below:

Coarse-grain : 8, 10, 12, 14, 16, 20,24

Medium-grai **30** **36** **46** **54** 60

Fine-grain : 80, 100, 120, 150, 180

Very fine grain : 220, 240, 280, 320, 400, 500, 600.

For all types of grinding higher limit is up to 180. The grit number above 200 is recommended for lapping operation etc.

Optional Elements are:

(1) *Prefix*,

It denotes manufacturer symbol for exact nature of abrasive e.g. GC. Here G is prefix and C stands for silicon carbide. This varies from manufacturer to manufacturer and they have their own code numbers.

(2) Structure,

(3) *Suffix*.

For an example use a wheel marked A36-L5-V23. The A refers to the abrasive which is aluminum oxide. The 36 represents the grain size. The L shows the grade or degree of hardness, which is medium. The 5 refers to the structure of the wheel and the V refers to the bond type.

Table 3.5: Commercial abrasive materials

Abrasive material	**Designation**	**Uses and Work material**	**Color**
Aluminum oxide 97-99% Al_2O_3 87-96% Al_2O_3	A	Safer and tougher than SiC, used for steels and high-strength materials, hardened steels, HSS, steels, cast iron	white pink to brown
Silicon carbide 96-99% SiC <96% SiC	C	Nonferrous, nonmetallic materials, CI, carbides, hard metals, and good finish, HSS, cemented carbides, aluminum, brass, brittle materials	green black
Cubic boron nitride (CBN)	B	Hard and tough tool steel, stainless steel, aerospace alloys, hard coating	
Synthetic diamond	D	Nonferrous metals, sharpening carbide, and WC tools, ceramics, cemented carbides	

There are **five characteristics that describe the abrasive material** on a cutting wheel.

1. The material itself, designated by a letter (A for Al_2O_3, B for CBN, C for SiC, or D for SD).
2. Grain size ranging from 8 (coarsest) 600 (finest).
3. The wheel grade is marked by a letter from A (soft) to Z (hard).

4. The grain spacing is labeled by a number from 1 (densest) to 16 (least dense).
5. The grinding wheel bonds in which the six most common are Vitrified (V), Resinoid (R), Silicate (S), Shellac (E), Rubber (R), Oxychloride (O)

Bonding materials commonly used in grinding wheels:

Vitrified: Most grinding wheels in common use are vitrified bonded wheels. Vitrified bonded wheels are unaffected by heat or cold and are made in a greater range of hardness than any other bond. They are strong and rigid, resistant to elevated temperatures, and relatively unaffected by cutting fluids. They adapt to practically all types of grinding with one notable exception: if the wheel is not thick enough, it does not withstand side pressure as in the case of thin cut-off wheels. Vitrified bonding material consists chiefly of ceramic materials.

Silicate releases the abrasive grains more readily than vitrified bond. Silicate bonded wheels are well suited for grinding where heat must be kept to a minimum, such as grinding edged cutting tools. It is not suited for heavy-duty grinding. Thin cut-off wheels are sometimes made with a shellac bond because it provides fast cool cutting.

Shellac bond grinding wheels are relatively strong but not rigid. They are often used in applications requiring a good finish;

Resinoid is strong and flexible. This bond is made of various thermosetting resin materials and have very high strength. It is widely used in snagging wheels (for grinding irregularities from rough castings), which operate at 9,500 surface feet per minute (SFPM). It is also used in cut-off wheels and rough grinding operations.

Rubber bond is the most flexible of the bonding materials. It is used as a bonding material in cutoff wheels.

Metallic bond, usually bronze, are the common bond material for diamond and CBN grinding wheels. Diamond and CBN abrasive grains are bond material to only the outside periphery of the wheel, thus conserving the costly abrasive materials.

Self-Check – 3.	

Name…… ID…… Date…….

Part. I:- Choose

Directions: Answer all the questions listed below. Examples may be necessary to aid some explanations/answers.

1. Which one types of testing or testing for conformance of the machined component?
   A. Performance B. Surface finish C. Shapes and dimensions D. None
2. Which is one must be included in a non-conformance report?
   A. Main reason error B. The solution to prevent the problem
   C. Explanation of corrective action to be taken D. All

Part. II: Short Answer Questions

Directions: Answer all the questions listed below.

1. Define the following terms
   a) Tolerance
   b) Actual size
   c) Allowance
   d) Deviations
2. What is the term for the theoretical size of a feature?
3. The RW of a surface grinder is rotating at a surface speed of 20 m/min. It is inclined at an angle of 5% with respect to the GW axis for roughing. What is the feed rate of the WP past the GW? If the inclination angle is reduced to 2° for finishing, what would be the feed rate in this case?

Operation sheet – 3.1	

Operation title: **Quality assure components in conformance to specifications**

Purpose: To develop the ability to determine a required grade of tolerance based on drawing and work standards

Steps / Procedures for Checking for conformance of components

Step 1 - Establishing Standards and Methods for Measuring Conformance

Step 2 - Measuring the Conformance

Step 3 - Determination of Whether the Conformance Matches the Standard,

Step 4 - Taking Corrective Action

Operation sheet – 3.2	

Operation title: **Grinding Parallels Steel (Block)**

Purpose: To develop the ability to perform intermediate grinding operations in accordance with operational standards

Material: Two pairs of parallels, firstly machined to rough dimensions, leaving a few millimeters to allow the rest to be ground and then hardened to 55 - 60 HRC

Specifications: Grade B - Lower surface tolerances Parallels are rectangular blocks, made from **steel**, which have 6 faces **ground** and finished to a precise smooth surface finish.

In Built Features: Description of Technical data and Standard Quality

- Variation in matched parallels is within 0.010 mm.
- Thickness, width and length are nominal and within ±0.1 mm upto 200 mm Length, ±0.2 mm upto 450 mm Length.
- Accuracy for Parallelism & Squareness is ±00005 mm upto 200 mm Length and ±0.010 mm upto 450 mm Length.
- All the four sides are chamfered.

Use:

Parallels are used in machining operations, to accurately support a clamped workpiece from underneath, to eliminate the workpiece being pushed down by the force of the cutting tool, to give clearance or raised evenly from the vise, keeping the work parallel; and it also used for comparison with a surface or machined face to check the flatness.

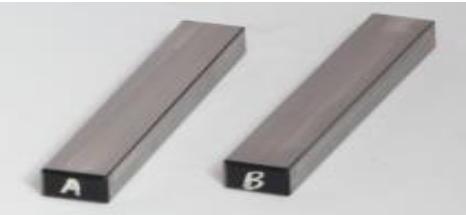
Condition for the operation: Fully organized work shop, good working condition

Precautions: - Wear protective clothing

Tools and equipment:

- Vernier caliper
- Students Guide
- Goggles

Working drawing of parallel steel (block)



- **Precautions:**Ckeck at least three times before starting the grinding opration the correct tetting up of machines and adjustement of tools.
- **Procedures** for Grinding parallel steel (block)

1) Two pairs of parallels, firstly machined to rough dimensions, leaving a few millimeters to allow the rest to be ground and
2) then hardened to 55 to 60 HRC.
3) They are then paired and placed in a grinding machine, and each face is ground until the overall dimensions are correct - they are paired during this stage so that even if the dimensions are not correct, they are still parallel to each other.
4) Then, the individual finishes are applied,
5) machining a chamfer along the edges to remove any burrs or sharpened edges

Quality criteria: The article must be made to the given dimensional accuracy.

LAP 3	**Practical Demonstration**

Name: _____ Date: _____

Instruction I: Given necessary machines, equpimentes, tools and materials you are required to perform the grinding operation of parallel steel (block) within 1:30 hours.

Task 1 The parallel steel (block must be made to the given dimensional accuracy within the given hours and must be submitted .

Reference Materials

1.Erik Oberg, Franklin D. Jones, Holbrook L. Horton, and Henry H. Ryffel, "Machinery's Handbook", 27th Edition, Industrial Press, Inc., New York, NY, 2004
2.Helmi A. Youssef and Hassen El-Hofy, "Machining technology, Machine tools and operations", Taylor & Francis Group, Boca Raton, London, New York, 2008
3.Fundamentals of machine tools, Training Circular No. 9-524, headquarters department of the army, Washington, DC, 29 October 1996
4.Shafizan Bt. Shariffuddin School of Manufacturing Engineering UniMAP
5.Inspection of Metals—Understanding the Basics, Copyright © 2013 ASM International F.C. Campbell, editor, All rights reserved www.asminternational.org
6.Machining and Machine Tools by A. B. Chattopadhyay.
7.Metal Cutting: Theory and Practice by A. Bhattacharya

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