MACHINING -LEVEL II

Based on Version 2 February 2017

Occupational Standard (OS)

Training Module –Learning Guide 31-33

Unit of Competence: Perform Intermediate Grinding Operations

Module Title: - Performing Intermediate Grinding Operations

TTLM Code: IND MAC2 TTLM10 1019v1

Module Title: - Performing Intermediate Grinding Operations

TTLM Code: IND MAC2 TTLM10 1019v1

This module includes the following Learning Guides

LG 31: Set up work

LG Code: IND MAC2 M10 LO1-LG 31

LG 32: Perform Intermediate Grinding Operations

LG Code: IND MAC2 M10 LO2-LG32

LG 33: Quality assure components in conformance to specifications

LG Code: IND MAC2 M10 LO3-LG33

Instruction Sheet	Learning Guide #31

This learning guide is developed to provide you the necessary information regarding the following **content coverage** and topics:

- Work requirements and sequence of operations
- Grinding Machines and their type
- Work holding devices
- Grinding wheels
  - ✓ Shape and grit/bond composition
  - ✓ Selecting, balancing**,** and dressing
- Accessories
- OHS measures and procedures

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**:

- Determine work requirements and sequence of operations from job specifications and according to standard procedures accordingly
- Select and apply correct and appropriate work holding devices
- Select, balance and dresses grinding wheels to form and size based on standard requirements
- Select accessories to facilitate production to task specifications.

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the "Information Sheets". Try to understand what are being discussed. Ask your trainer for assistance if you have hard time understanding them.
4. Accomplish the "Self-checks" which are placed following all information sheets.
5. Ask from your trainer the key to correction (key answers) or you can request your trainer to correct your work. (You are to get the key answer only after you finished answering the Self-checks).
6. If you earned a satisfactory evaluation proceed to "Operation sheets
7. Perform "the Learning activity performance test" which is placed following "Operation sheets" ,
8. If your performance is satisfactory proceed to the next learning guide,
9. If your performance is unsatisfactory, see your trainer for further instructions or go back to "Operation sheets".

Information Sheet – 1.1	Work requirements and OHS

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

To get the maximum benefit from the training, it is essential that you use every opportunity to consolidate what you observe and to interact between yourself and staff member in charge of your training. 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.

Work requirements and sequence

- **Working drawings**

The term **working drawing** is used to describe the complete set of drawing produced by the designer, manufacturer, or fabricator that show the shape and detailed dimension and contain parts list, or bill of materials (BOM) and information needed for assembly of a product to be made based on its design.

Working drawing describe every component in a more precise detail way that will enable them to be constructed and operated without errors, delays or other costly issues. The primary role or function of working drawings is to convert design data into finished part information /instructions and to clearly communicate that information to building industry, code officials, product manufacturers, suppliers and fabricators. It helps streamline the manufacturing process.

- **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.

OHS measures and procedures

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 – 1	Written test

Name…………………………………………… ID………………………… Date…….

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

Test I: Choose the best answer (4 point)

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

Test II: Short Answer Questions

1. List duties of grinding machine operator (5 point)
2. Write down all the safety requirements for grinding machine. (3 point)
3. Write three examples of Hazards parts of machines? (3points)
4. Essential element of a working drawing is ______________ ? (2point)
5. The first activities to make desired shape and size a product or project is to do __________ (2point)
6. What are the common causes of grinding accidents? (2point)

You can ask you teacher for the copy of the correct answers.

Note: **Satisfactory rating - 10 points** **Unsatisfactory - below 10 points**

Information Sheet – 2	Grinding Machines

Grinding machine

Grinding is the process of removing metal by the application of a rotating abrasive wheel which is made of crushed or ground abrasive grains bonded together. When the moving abrasive particles contact the work piece, they act as tiny cutting tools, each particle cutting a tiny chip from the work piece. The grinding wheel is usually disk shaped and is precisely balanced for high rotational speeds. The development of abrasive materials and better fundamental understanding of the abrasive machining have contributed in placing grinding among the most important basic machining processes. Grinding is generally the most accurate final operations performed on manufactured products and extreme important processes in production work.

A **grinding machine** is a machine tool used for producing very fine finishes or making very light cuts, using an abrasive wheel as the cutting device. It can be used to achieve ultimate dimensional precision and surface finish. The grinding machine supports and rotates the grinding abrasive wheel and often supports and positions the work piece in proper relation to the wheel. The grinding machine is used for roughing and finishing flat, cylindrical, and conical surfaces; finishing internal cylinders or bores; forming and sharpening cutting tools; snagging or removing rough projections from castings and stampings; and cleaning, polishing, and buffing surfaces.

Grinding operations are an extremely versatile machine used to perform a variety of grinding operations: surface, cylindrical, or complex shapes. The basic **types of grinding** processes are surface grinding, cylindrical grinding, and centerless grinding. Each basic operation has a number of variations and selection determined by the size, shape, features and desired production rate. It is carried out with a variety of wheel-work part configurations/ relationship. The operation of this machine requires understanding and skills of maintaining this relationship between the grinding wheel and the metal being cut.

Nowadays, grinding is **mainly used** for the following purposes:

(1) To remove a very small amount of metal from the work piece to bring its dimensions within very close tolerances after all the rough finishing and heat treatment operations have been carried out. It is thus basically a finishing process employed for producing close dimensional and geometrical accuracies.

(2) It is sometimes used to obtain better finish on the surface.

(3) Sometimes it is used for machining those hard surfaces which are otherwise difficult to be machined by the high speed steel tools or carbide cutters.

(4) This also used for sharpening the cutting tools.

(5) It is used for grinding threads in order to have close tolerances and better finish.
(6) It is also employed for removing weld beads and cleaning surfaces

- **Cutting Action in Grinding**

The action of grinding wheel is very similar to that of milling cutter. A **grinding wheel** consists a large number of abrasive particles, bonding material and voids. When the moving abrasive wheel contact the workpiece, each of the projecting abrasive particle act as tiny single cutting tool tips and remove metal with undefined geometry cutting edges but usually with high negative rake angle (as the concept illustrated in the Figure 1 and 2).

Projecting grains abrade layers of metal from the work in the form of very minute chips (similar to that obtained by milling) as the wheel rotes at high speeds of up to 60 m/s. However, in grinding, not all the grains participate equally in the metal removal as in milling. Owing to the small cross-sectional area of the chip and the high cutting speed, grinding is characterized by high accuracy and good surface finish. Consequently, it is usually employed as a finishing operation.

A properly **selected** grinding wheel exhibits self-sharpening action. As cutting proceeds, the abrasive particles, at cutting edge become **dulled**, and eventually these become **cracked** along the cleavage planes due to resistance offered by work pice material which resists the cutting action. Thus **new cutting points** are produced which carry out further cutting action. This process continues till the abrasive grains get worn down till the level of bond. At this point the **bond** allows the remainder of the worn grains to be torn from the wheel, exposing new grains which were previously below the surface of the wheel and the new grains do further cutting action.

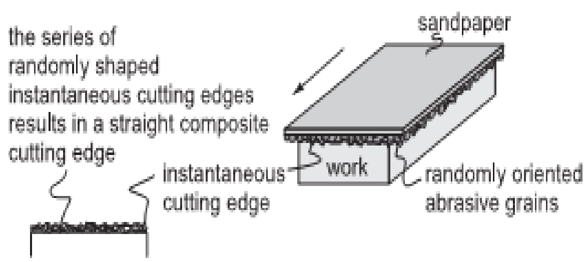


Figure 1. The concept of undefined cutting edge in abrasive machining. (Source: Valery Marinov, Manufacturing Technology

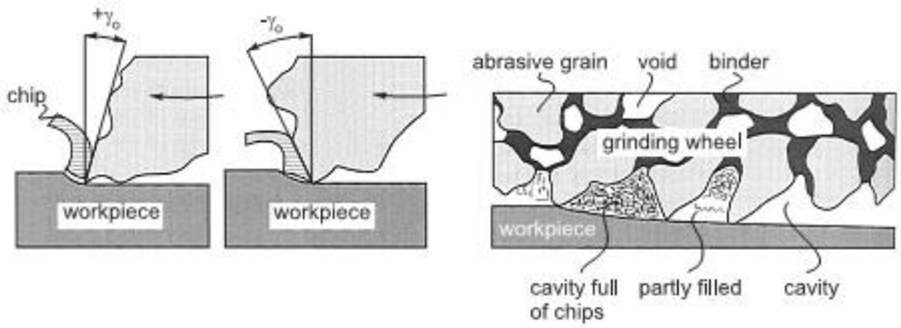


Figure 2. (Left) The rake angle of a single grain can be zero or positive but usually is highly negative. (Right) The structure of a grinding wheel showing the cutting action of abrasive grains.

- **Specific features of grinding process**

Along with the general features of other typical methods of machining, the grinding process has certain specific features of its own, such as the following:

- In contrast to the teeth of a milling cutter, individual grains of a GW have an irregular and non-definite geometry. They are randomly spaced along the periphery of the GW.
- The radial positions of the grains (protruding) on the wheel periphery vary, which make the grains cut layers of material in the form of chips of different volumes (Figure 2.).
- The grains of the GW are characterized by high negative rake angles of −40° to −80°, consequently, the shear angles are very small (Figure 2.).
- Owing to the minute chip thickness and the highly abrasive negative rakes of the grinding operation, the specific cutting energy in grinding is considerably larger than that of operations using tools of definite geometry. Grinding is thus not only time-consuming but also power-consuming and is hence a costly operation.
- The GW has a self-sharpening characteristic. As the grains wear during grinding, they either fracture or are torn off the wheel bond, exposing new sharp grains to the work.
- The cutting speeds of GWs are very high, typically 30 m/s, which together with the minute chip removal of the grains provide high dimensional and form accuracy along with high surface quality.

- **Advantages of grinding possesses**

These features make the grinding process more complicated than the other kinds of machining processes and offer considerable difficulties in both theoretical and experimental investigations. However, grinding possesses certain advantages over other metal cutting methods:

- It is the only method of removing material easily from materials after hardening. Parts requiring hard surfaces are first machined to shape in annealed condition, with only a small amount left as the grinding allowance, considering the tendency of material to warp during hardening operation.
- Grinding unlike conventional machining need not cut through the hard skin of forgings, etc.
- Very accurate dimensions and smoother surfaces can be achieved in a very short time due to large number of cutting edges on the grinding wheel.
- No marks as a result of feeding are there, because the wheel has considerable width.
- Complex profiles can be produced accurately with relatively inexpensive operation. Very little pressure is required, thus permitting very light work to be ground that would otherwise tend to spring away from the tool. This characteristic permits the use of magnetic chucks for holding the work in many grinding operations.
- Abrasives have very high hardness; are less sensitive to heat compared to other tool materials and can sustain high temperatures. Thus these can be worked at higher cutting speeds. Grinding wheels have self-sharpening properties due to releasing of dulled grains and exposing new sharp ones.

- **Types of grinding machine**

Grinding machines are designed principally to finish parts having cylindrical, flat or internal surfaces. The kind of surface machined largely, determines the type of grinding machine and thus a machine grinding flat surfaces is called a surface grinder and a machine grinding cylindrical surfaces is called the cylindrical grinder and so on. In case of special purpose machines, they are designated according to the type of operation they perform. The common types of grinding machines based on the type of surface generated or work done include the following: (1) plain cylindrical, (2) internal cylindrical, (3) centreless, (4) surface, (5) off-hand, (6) special, and (7) abrasive-belt.

Here is a broad classification of grinding machines based on the type of surface generated or work done.

<table>
<tr><td>1. Cylindrical grinder
a. Work between centers,
b. Chucking type cylindrical grinders
c. Centre less,
d. Tool-post,
e. Crank-shaft and other special applications</td><td rowspan="2">2. Surface grinder
(a) Planer type (Reciprocating table)
(1) Horizontal spindle,
(2) Vertical spindle
(b) Rotating table
(1) Horizontal spindle,
(2) Vertical spindle</td></tr>
<tr><td>Internal grinder
(a) Work rotated in chuck,
(b) Work rotated and held by rolls.</td></tr>
</table>

(c) Work stationary.	
3. **Tool and cutter grinding**: it is the generally complex operation of forming and resharpening the cutting edges of tool and cutter bits, gages, milling cutters, reamers, and so forth. It may be divided into the following classes: i. Universal. ii. Special. (i) Drill, (ii) Tool-bit, (iii) Cutter (iv) Pedestal etc.	4. **Special grinding machines** (a) Swinging frame — snagging, (b) Cut-off-sawing (c) Portable — off-hand grinding (d) Honing lapping—accurate finishing (e) Super finishing, • Disk, • Flexible band • Buffing machine. (f) Flexible shaft — general purpose.

I. Bench and floor (pedestal) grinders

The grinding of the cutting edges of general lathe tool, shaper tool, drill bit points and chisels, the forming of blades and other tools that need to be made or shaping /repaired, and various other metal removing processes such as reducing weld marks and imperfections on workpieces etc. all may be performed on a simple grinding machine. This machine is called a bench grinder if it is mounted on a workbench. The terms floor or pedestal grinder are used interchangeably when the grinding head is mounted on a pedestal for large workpieces.

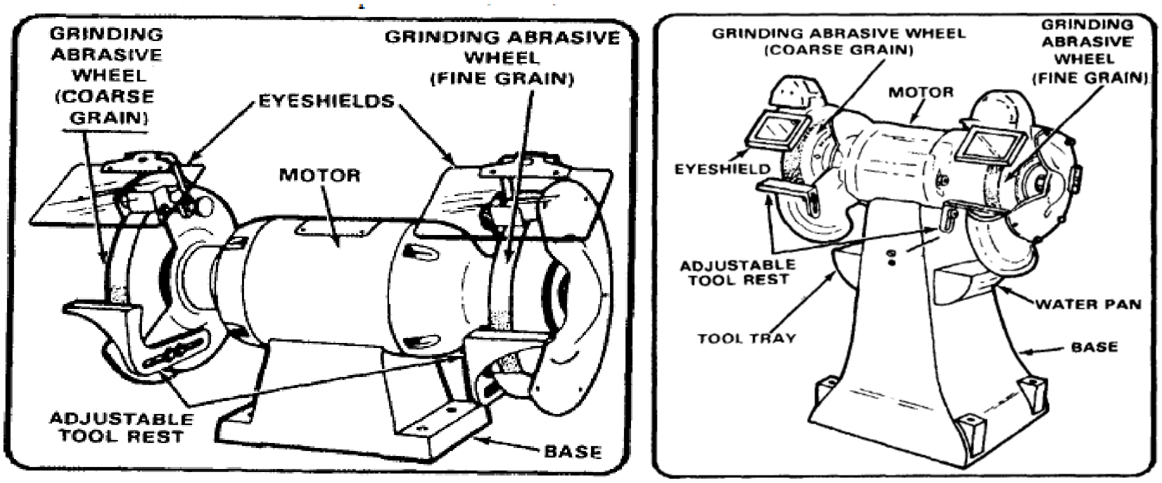


Figure 3. Bench and Pedestal (Floor) mounted utility type grinding machine

Bench grinder which usually operated manually has two wheels of different grain sizes for roughing and finishing operations.

Pedestal grinder is very similar to bench grinder except it is bigger in size of its wheels, power and also on the floor. Pedestal grinders range in size from grinders used for small tool, grinding operations to large grinders used for heavy duty, rough snagging processes on large forgings and castings.

Construction and features of Bench and floor (pedestal) grinders

Regardless of the type, bench and pedestal (floor) grinders have a direct power driven spindle. The spindle is flanged and threaded at both ends to receive the grinding wheels. **(07/01)** One end of the spindle has a right-hand thread, the other end a left-hand thread. The thread direction safeguards the wheel from loosening during starting and during cutting action.

Grinding wheels **(07/01)** are mounted directly on the spindle of bench and floor grinders. The grinding wheel at one ends is coarse, for rough cutting operations. The wheel on the opposite end is fine, for finish grinding. Each grinding wheel is held between two flanged collars. There is a simple adjustable work rest **(07/03)** for each wheel. Each rest provides a solid surface upon which the part may be positioned horizontally at an angle to the wheel face. Wheel guards **(07/02)** and the protective sheets **(07/01)** are important parts of the grinder. The wheel guards and the protective sheet permit the work surface to be observed and other particles. However, because of the hazards of machine grinding it is also necessary for the worker to use personal eye protection devices.

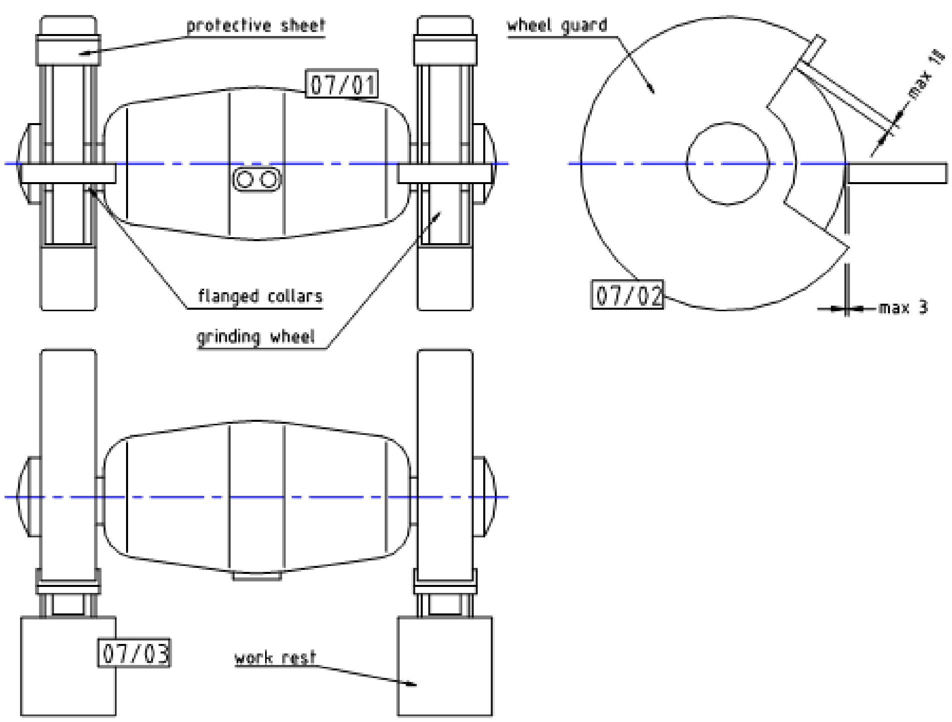


Figure 4. Construction and features of Bench and floor (pedestal) grinders

Offhand grinding processes

Grinding operations on the bench or floor grinder are referred to as offhand grinding. In offhand grinding, the process of positioning and feeding the workpiece against a revolving face of the grinding wheel is done by hand. Deciding depth of cut and feed is based on the operator's knowledge of grinding.

Bench and pedestal (floor) grinders have a direct power driven spindle which is generally have fixed spindle speeds and fixed wheel size requirements, so that the cutting speed of the wheel is constant and cannot be changed for different materials. Therefore, the operator must use care in feeding and not overload the wheel by taking too heavy a cut, which would cause excess wear to the grinding wheel. Similarly, he must be careful not to glaze the wheel by applying excessive pressure against the wheel.

The one variable factor in most offhand grinding is the selection of grinding abrasive wheels, although limited to one diameter. For example, a softer or harder wheel can be substituted for the standard medium grade wheel when conditions and materials warrant such a change.

II. Surface grinding processes

The grinding of flat or plain surfaces is known as surface grinding. Surface grinding is the most common an abrasive machining process in which a rotating grinding wheel removes material from the simple plain flat surfaces of the workpiece. However, the grinding wheel is not limited to just a cylindrical shape, but can have a myriad of options that are useful in transferring different designs to the object being worked on.

Surface grinding is a finishing process that smooths the surface of metallic or nonmetallic materials and gives them a more refined look. Angular or formed surfaces can also be ground by using special fixtures and form dressing devices.

Surface grinding is characterized by a large contact area of the wheel with the workpiece, as opposed to cylindrical grinding where a relatively small area of contact is present. As a result, the force of each abrasive grain against the workpiece is smaller than that applied to each grain in cylindrical grinding. In surface grinding the grinding wheel should be generally softer in grade and wider in structure than for cylindrical grinding.

The **surface** grinder is composed of an abrasive wheel, a work-holding device chuck and a reciprocating table for different methods of surface generation. Two general types of machines have been developed for this purpose.

1. Rotary-type is one in which the table is circular in shape and rotates under the reciprocating wheel. Its spindle can be horizontal or vertical. (The principle is shown in Figure. 5c and 5d)
2. Planer-type is one in which the table is rectangular and traverses or reciprocating under the wheel. Its spindle can be horizontal or vertical. (The principle is shown in Figure. 5a and 5b)

Each type of surface grinding machine has the possible variations of having the grinding wheel spindle in either a horizontal or a vertical position and the relative motion of the workpiece is achieved either by reciprocating the workpiece past the wheel or by rotating it. The possible combinations of spindle orientations and workpiece motions yield four types of surface grinding processes as illustrated in the Figure 5. Of the four types, the horizontal spindle machine with reciprocating worktable is the most common.

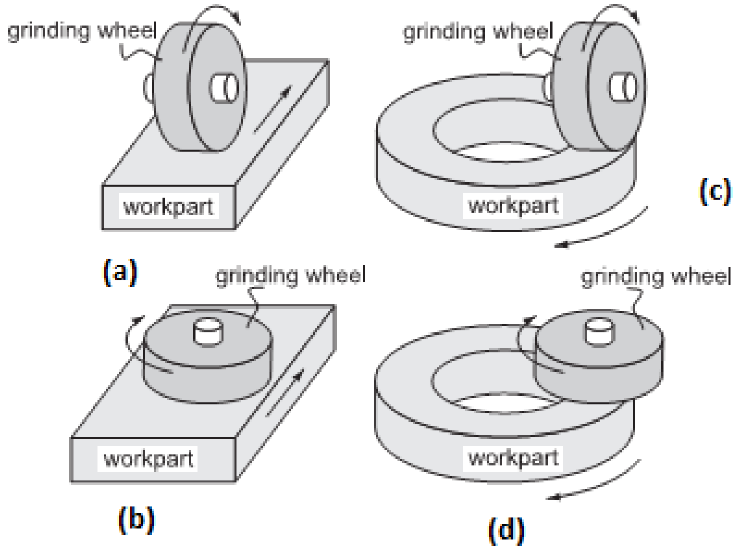


Figure 5. Four types of surface grinding with horizontal or vertical spindles, and with reciprocating linear motion or rotating motion of the work piece

Factors to consider when surface grinding

The cutting process parameters, feed rate, cutting velocity, and depth of cut are defined as those for peripheral and face milling. The table on which the workpiece is placed can translate or rotate in a planar motion with respect to a fixed-axis rotating grinding wheel. The table (i.e., the workpiece) is brought up by an increment equal to the depth of cut once the current pass has been completed (typically achieved by lowering the grinding wheel, as opposed to raising the table).

The three most important **factors to consider when surface grinding** are:

1. the material of the grinding wheel,
2. the material of the piece being worked on, and
3. the grinding fluid.

Surface Grinding Machines and Related Operations

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.

1. **Horizontal-spindle reciprocating-table grinders.** Figure 6. 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.

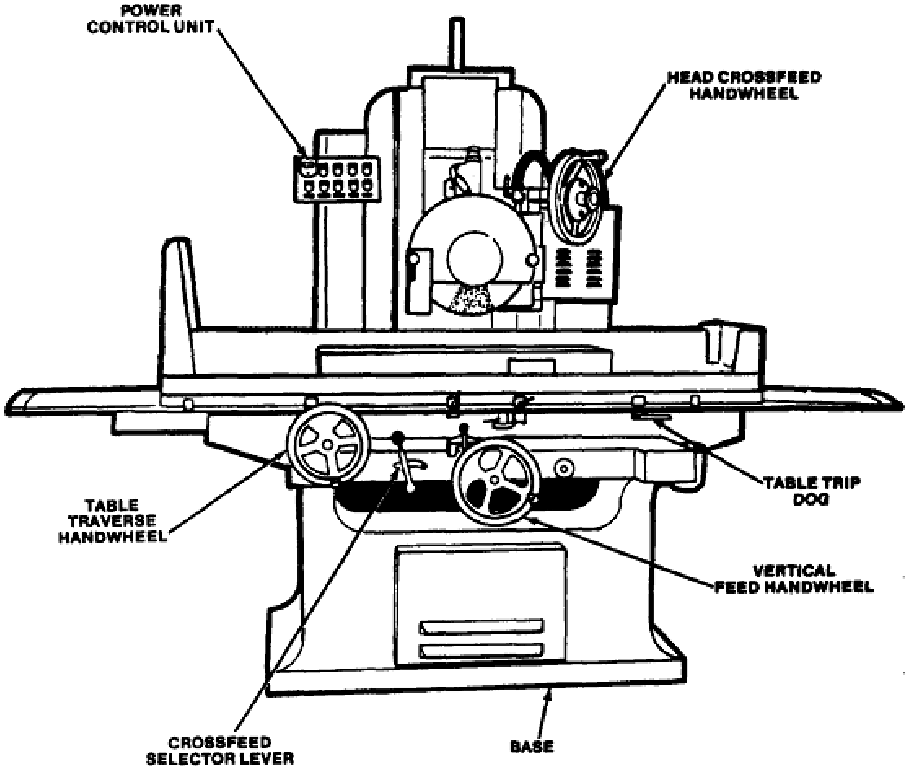


Figure 6. Horizontal-spindle reciprocating-table Surface grinder

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 workpiece 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).
c. **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.

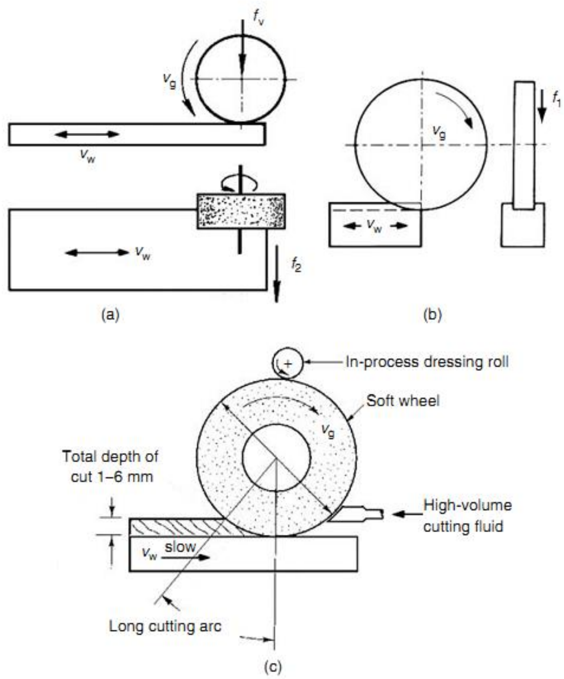


Figure 7. Operations performed on horizontal-spindle reciprocating table grinders. (a) Transverse grinding, (b) plunge grinding, (c) CFG.

3. **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.

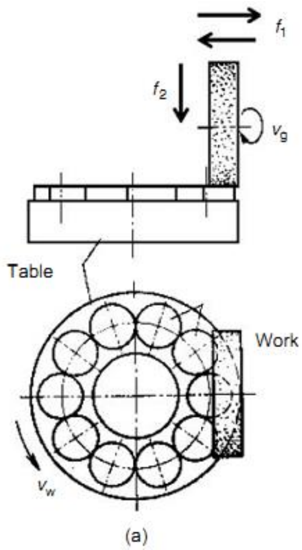


Figure 8. Operations performed on Horizontal spindle rotary-table grinders.

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 f (Figure 9a).

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).

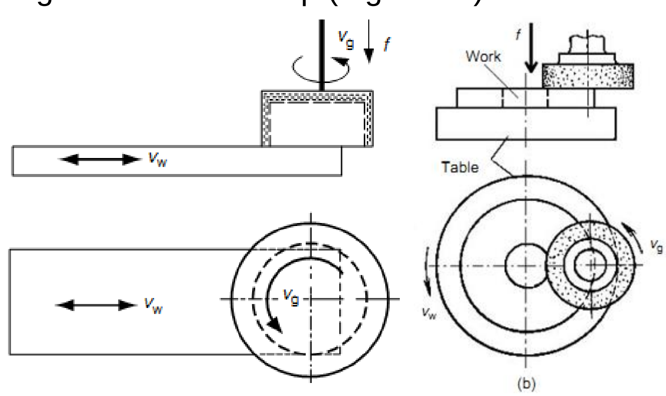


Figure 9. Operations performed on vertical-spindle grinders (a) reciprocating table and (b) rotary-table grinders

III. Center-type Cylindrical grinding

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.

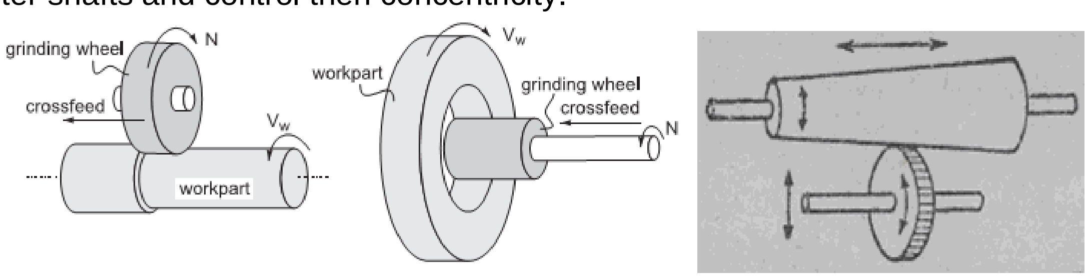


Figure 10. Types of Cylindrical grinding operations: external, internal, and taper (from left to right)

1. **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

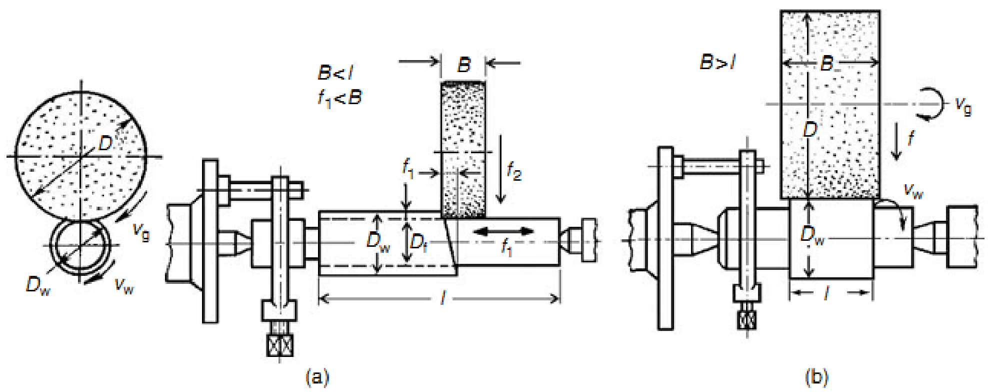


Figure 11. External cylindrical grinding operations.

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 workpiece, 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.

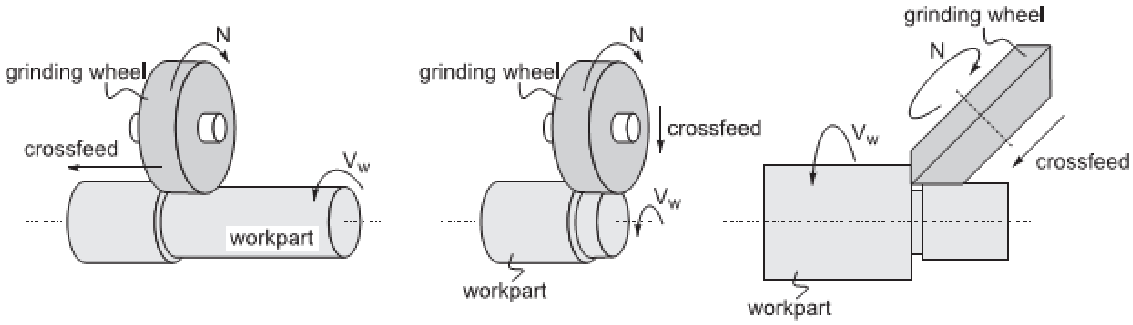


Figure 12: Three types of cylindrical grinding: (From left to right) traverse feed grinding, plunge grinding, a combination of both previous types.

1. **Universal cylindrical grinding machines**:

Universal-type grinders make it possible to swivel both the workpiece 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. **Internal grinding machines**

Listed below are the proper procedures and methods to perform internal grinding. Internal grinding is done with the universal tool and cutter grinder with an internal grinding attachment (Figure 13). Note that the belt and pulleys are exposed; during actual operation, this area should be covered with a guard. Since internal grinding uses small grinding wheels, the spindle and quill must operate at a high speed to get the required surface feet per minute (SFPM). 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.

One condition that is more pronounced in internal grinding than in external grinding is that the larger area of contact may cause the wheel to load and glaze quickly which in turn causes vibration and produces poor surface finishes. Therefore, it is important to pay particular attention to the condition of the wheel and to use either a coarser grain wheel to provide more chip clearance or a softer grade wheel that will break down more easily. During grinding, let the grinding wheel run out of the end of the hole for at least one-half the width of the wheel face but not more than two-thirds. If the wheel clears the work each time the table reciprocates, it will grind bell-mouthed hole because of spring in the quill.

Internal conical tapers can also be ground on a universal grinding machine, using a combination of the rules for external conical grinding and those for straight internal grinding. The main thing to remember is to be sure that the axis of the quill is at center height with the axis of the work.

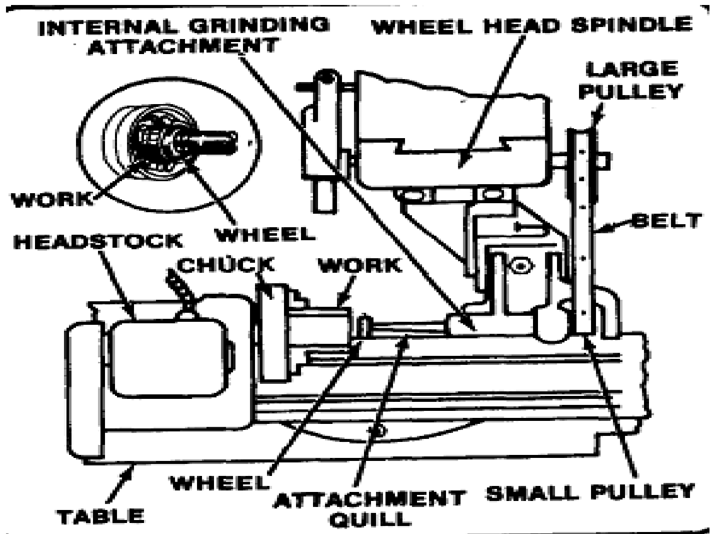


Figure 13. Internal grinding setups.

I. Centerless grinding

Centerless grinding process plays an important role in the sphere of grinding. As the name implies, the work is not supported between centers but is held against the face of grinding wheel by the combination of supporting rest and a regulating wheel. Thus centereless grinding does not require centre holes, drivers and other fixtures or holding the workpiece. During the process, the workpiece is supported on a work rest blade and the regulating wheel holds the workpiece against the horizontal force of action controlling its size and imparting the necessary rotational and longitudinal feed. The blade on the work rest gives the necessary support to the workpiece against the cutting forces. The thickness of the blade is usually slightly less than the diameter of the workpiece for smaller diameters and maximum thickness is around 20 mm. The slope (“2 ° to 8°) of its edge with the regulating wheel provides the V formation into which the work seats. Work guides are also used to keep the work parallel with the space between the wheels. The speed of regulating wheel varies from 15 to 60 meters/mm. (while the speed of grinding wheel is maintained at 1800 meters/minutes). The workpicce is usually ground with its centre above the line of centers of the wheels by about half the diameter of workpiece, the maximum value being 12 mm. (Figure 14. shows the principle of centreless grinding).

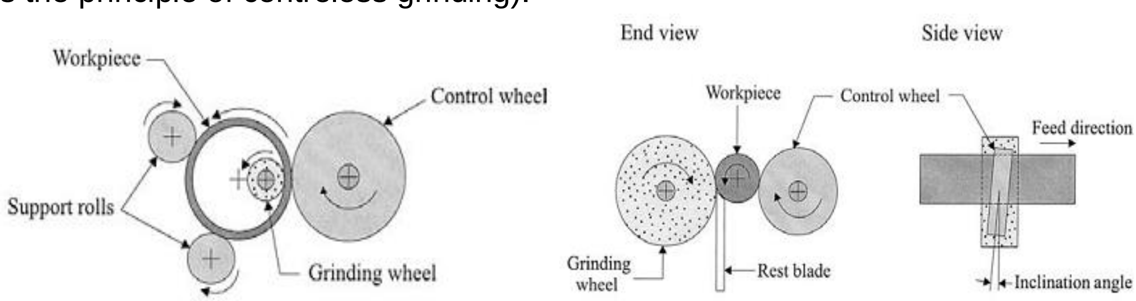


Figure 14: Centerless (a) internal and (b) external grinding.

The workpiece is ground between two grinding wheel wheels. The larger one is used to grind the surface of the workpiece, while the smaller (regulating wheel) which is tilted at an angle i to the grinding wheel, is used to regulate and control the velocity V_f of the axial movement (through feed) of the workpiece. The velocity component can be resolved into two parts, the one in horizontal direction is V sin cx which gives the necessary Iced, while the other one V cos a in the vertical direction gives rotational motion to the wheel. The rotation of wheel is such that the worpiece rotates in downward direction as this position can be balanced by the work-rest. A continuous line of parts can be fed into the external grinding system, whereas parts are machined one at a time in internal grinding.

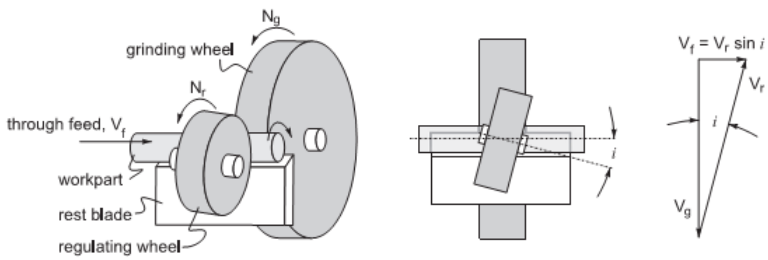


Figure 15: External traverse feed centerless grinding.

Scope of the centreless grinding

Centerless grinding is a process for continuously grinding of internal or external cylindrical surfaces and it is ideal for mass production. It can also be external or internal, traverse feed or through-feed or in-feed/plunge grinding. The most common type of centerless grinding is the external traverse feed grinding. It requires special machines that can do no other type of work.

The process can be applied to the workpieces upto 15 cm in diameter and from washer to bars of 6-7 meters in length. With the in-feed and end-feed methods, tapered, headed, stepped and formed work can also be ground. The accuracy that can be obtained from centreless grinding is of the order of 0-00025 mm and with suitably selected wheels, the finish satisfies the most exacting requirements.

Typical parts made by centerless grinding are roller bearings, piston pins, shafts, and similar components. Parts with variable diameters, such as bolts, valve tappets, and distributor shafts, can be ground by plunge centerless grinding. Sleeve-shaped parts and rings can be ground by the internal centerless grinding, in which the workpiece is supported between three rolls and is internally ground. The primary advantage of this process over cylindrical grinding is reduction in setup time.

Advantage of centerless grinding

In comparison to cylindrical grinding, it has the following advantages:

- The rate of production is much greater than cylindrical grinding.
- The work is supported rigidly along the whole length, ensuring better stability and accuracy.
- Less grinding allowance is required, as the work centers itself during operation. As the centering is eliminated, less stock is needed.
- This process is very suitable for long jobs as the work is supported along the whole length and thus deflection does not occur.
- No holding of the workpiece is required except the work support and hence the long bars can be ground easily without any deflection being produced.
- Work of very small diameter can be ground using external centerless grinding.
- Due to floating conditions, the centering is unnecessary and can be eliminated and hence no time is lost in job setting and the cost to provide centers is eliminated.
- The machine is easy and economical to maintain, as the wear and Lear of the machine is less
- The production cost is considerably lower.
- The process can often be made automatic.
- The operation becomes automatic by employing continuous macazine feed for longer bars and hopper for small jobs.
- Very little skill is required of the operator.

The major disadvantages are as follows:

- Special machines are required that can do no other type of work.
- The work must be round; that is, l at surfaces or keyways cannot be worked on.
- This process is only used in case of straight cylindrical parts. If there is a head on the workpiece or it is tapered one, then this process cannot be used.
- In grinding tubes, there is no guarantee that internal and external diameters are concentric. Concentricity cannot be maintained.
- Since the roundness of internal surface depends upon the external surface, the external surface must be ground first and internal grinding afterwards
- Form grinding operation cannot be carried out by this process.
- A most common defect of centerless grinding is lobbing (unevenly ground external surface). It occurs during grinding of steel bars whose surfaces have some high and some low spots due to hot or cold rolling, cannot be ground.

Methods of centreless grinding

Basically there are three different methods by which centreless grinding can be done on different types of jobs.

1. **Through-feed.**

This is simplest method and is applied only to plain parallel parts such as roller pins and straight long bars which are difficult to grind by ordinary cylindrical grinding method. In this case, controlling wheel is first positioned for the proper diameter, i.e. the gap between the regulating wheel and grinding wheel is adjusted equal to the desired diameter of the workpiecc and then the job is fed and passed through the wheels. The machine can remove up to 0.38 mm of stock on the diameter in one pass. The rate of longitudinal feed = it x diameter of regulating wheel x r.p.m. of regulating wheel x sin (angle of inclination of regulating wheel, usually 10 to 6). This relationship does not consider effect of slip. For finish grinding, high speed of regulating wheel combined with less inclination are used and vice versa.

2. **In-feed (Plung-cut-grinding)**

This method of grinding is used when the workpiece is of headed, stepped or taper form. In this case there is no axial movement of the workpiece as the length of grinding has to be controlled. The only movement occurring during the process is the rotating movement. During the process the workpiece is placed on the work-rest against an end stop and then the control wheel is advanced towards grinding wheel by some lever arrangement, and grinding continued till the workpiece is reduced to the required diameter. The regulating wheel is given a slight inclination of the order of ‘2 in order that the workpiece may remain tight against the end stop. If this inclination is not given to the controlling wheel, then there are chances that workpiece may fall down during the process. The length of the workpiece that can be ground is limited to 30 cm. By this process form grinding can also lx done.

3. **End-feed**

This process of centreless grind. is used for headed components which are too long to be ground by the infeed method. End-feed grinding i.e. when the length of workpiece is greater than the width of the grinding wheel. The work is fed as in case of in-feed method and after a certain portion of length of workpiece has been ground, the axial movement takes place until the whole of length has been ground. It is also used for tapered work. Usually both grinding wheel and regulating wheel are trued to obtain the required taper.

4. **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.

Pre-grinding When a new tool has been built and has been heat-treated, it is pre-ground before welding or hard facing commences. This usually involves grinding the **OD** slightly higher than the finish grind OD to ensure the correct finish size.

5. **Internal cenireless grinding**

This process is of recent development and is used for grinding internal surfaces of the relatively long workpieces. The workpiece is supported by a set of rollers A and fl and a regulating wheel R. One of the rollers simply serves the purpose of supporting and hence is called the supporting roller; the other is used for pressing the workpiece against the regulating wheel and hence is called the pressure roller. The grinding wheel G and the workpiece rotate in the same direction while the regulating wheel in the opposite direction. Another point of difference in the internal surface grinding is that grinding wheel is smaller in diameter than the regulating wheel. These grinders are used for grinding internal bores and tubes which are generally tapered and those having more than one diameter. It is frequently used on production arts that have not been heat treated to save the reaming cost. According to the construction, there are several types of internal grinders.

(a) The work is rotated on the outside diameter by driven rolls, thus making it possible to grind the bores absolutely concentric with the outside diameter. This arrangement lends itself to production work since loading may be simplified and magazine feed may be used. This type of grinding operation is called internal centreless grinding (Figure 16a)

(a) The wheel is rotated and at the same time reciprocated back and forth through the length of hole. The work is rotated slowly. This type of grinder is also called chucking grinder (Figure 16b).

(b) The work remains stationary and the rotating wheel spindle is given an eccentric motion, according to the diameter of hole to be ground. Such a type of operation is used where the work is difficult to be rotated. Since in this operation, the motion of the grinding wheel is in the form of planet and hence it is frequently called planetary grinding (Figure 16c).

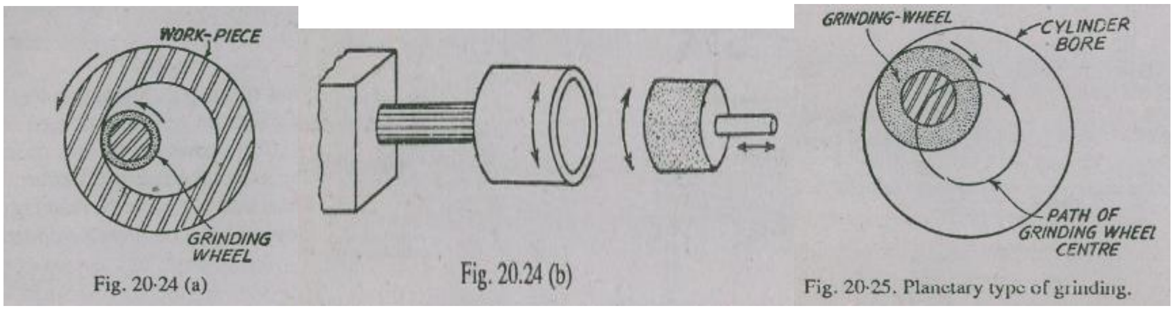


Figure 16. Types of internal grinder

Self-Check – 2	Written test

Name…………………………………………… ID………………………… Date…….

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

Test I: Short Answer Questions

1. Write down all the safety requirements for grinding machine.
2. Write three examples of Hazards parts of machines?
3. What are the main purpose of grinding machines?
4. Write down some of the grinding machines.
5. What are the main standard equipment of grinding machines?
6. What is CFG and how does it differ from conventional plunge surface grinding?
7. Explain why CFG has become an important process
8. What are the common causes of grinding accidents?
9. What other machine tool does a cylindrical grinding resemble?
10. Explain the major differences between the specific energies involved in grinding and in machining.

Note: **Satisfactory rating - 5 points** **Unsatisfactory - below 5 points**

You can ask you teacher for the copy of the correct answers.

Information Sheet – 3	Grinding wheel

3.1. Grinding wheel

Grinding is a material removal process in which abrasive particles (made of crushed or ground abrasive grains) are contained in a bonded grinding wheel that operates at very high surface speeds. A grinding wheel consists of a closely packed abrasive particles (grains) that are held together by bonding material. The bonding material holds the particles in place and establishes the shape and structure of the wheel. The grinding wheel is usually disk shaped and is precisely balanced for high rotational speeds.

When a grinding wheel is functioning properly, the abrasive grains cut very small chips from the workpiece and at the same time a portion of the bond of the wheel is worn away. As long as the bond is being worn away as fast as the abrasive grains of the wheel become dull, the wheel will continue to work well. If the bond is worn away too rapidly, the wheel is too soft and will not last as long as it should. If the cutting grains wear down faster than the bond, the face of the wheel becomes glazed and the wheel will not cut freely.

The grinding wheel has abrasive grains enveloped in a matrix of bonding material (Figure. 17a). These grains are of irregular shape and randomly dispersed within the matrix. Owing to this random dispersion, three mechanisms of interactions exist between the grains and the workpiece: cutting, plowing, and rubbing. Only cutting causes material removal, while plowing only causes deformation of the surface (Figure. 17b). The abrasive particles are hard, brittle refractory materials that are classified according to their hardness, toughness, and friability (capacity to fracture and yield another cutting edge, in contrast to gradual wear into a dull shape).

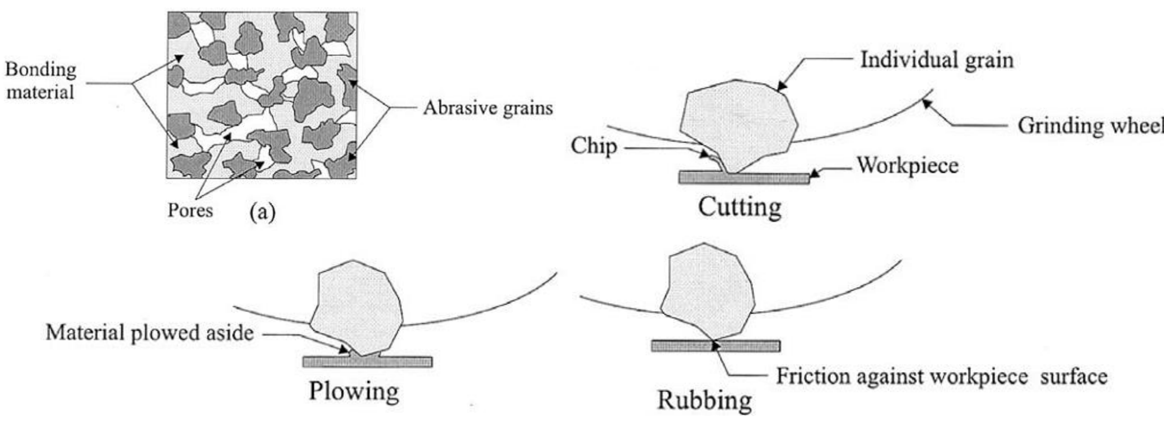


Figure 17 (a) Grinding wheel structure; (b) material removal.

- **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.

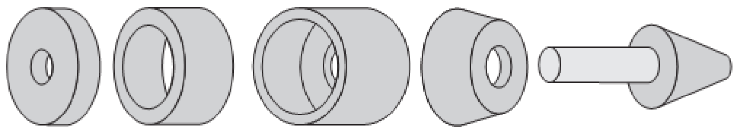


Figure 18: Some common types of grinding wheels; (From left to right) straight, cylinder, straight cup, flaring cup, mounted.

Straight wheels: numbers 1, 2, and 3, are commonly applied to internal, cylindrical, horizontal spindle, surface, tool, and offhand grinding and snagging. The recesses in type numbers 2 and 3 accommodate mounting flanges. Type number 1 wheels from 0.006-inch to l/8-inch thick are used for cutting off stock and slotting.

Cylinder wheels: type number 5, may be arranged for grinding on either the periphery or side of the wheel.

Tapered wheel type: number 4, take tapered safety flanges to keep pieces from flying if the wheel is broken while snagging.

Straight Cup wheel, type number 6, is used primarily for surface grinding, but can also be used for offhand grinding of flat surfaces. Plain or bevelled faces are available.

Flaring Cup wheel, type number 7, is commonly used for tool grinding. With a resinoid bond, it is useful for snagging. Its face may be plain or bevelled.

Dish wheel, type number 8, 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.

Grinding Wheel Geometry

GW shapes must permit proper contact between the wheel and the surfaces to be ground. Figure 19. illustrates eight standard shapes of GWs, whose applications are as follows:

- 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.

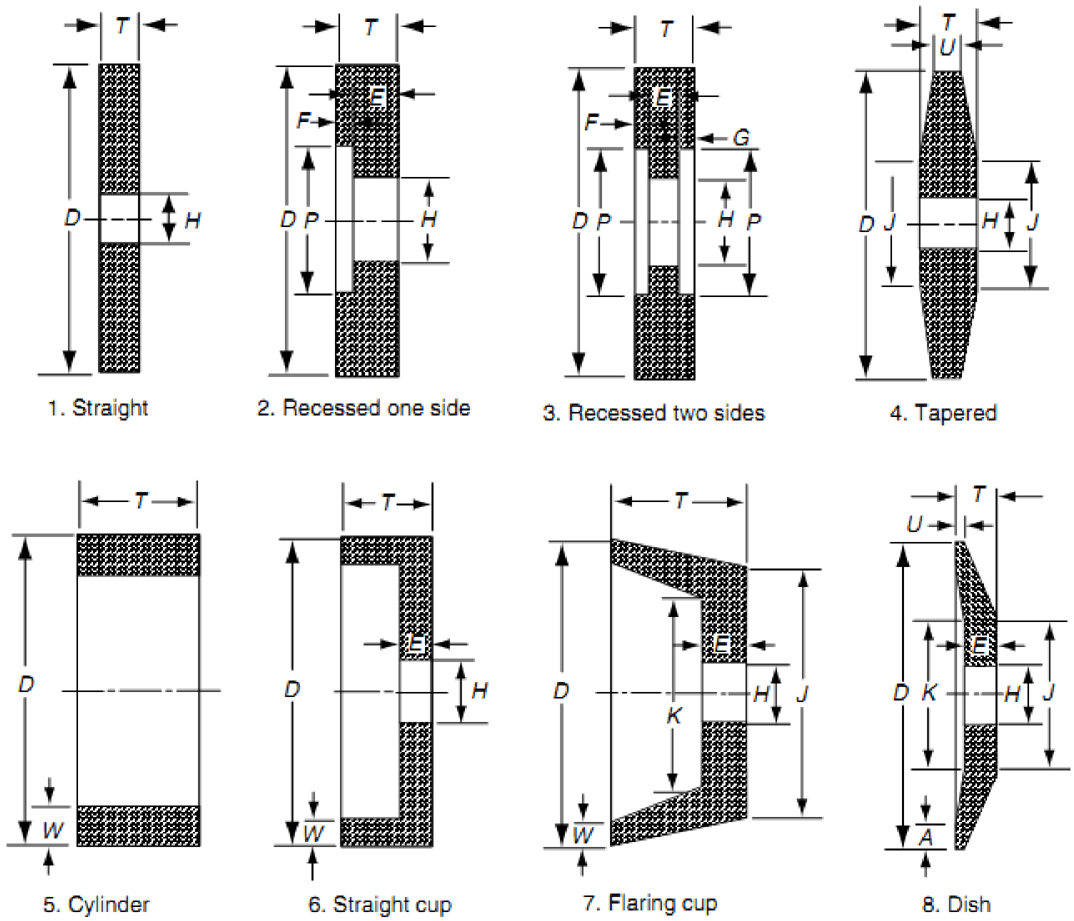


Figure 19. Standard types of grinding wheels

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.

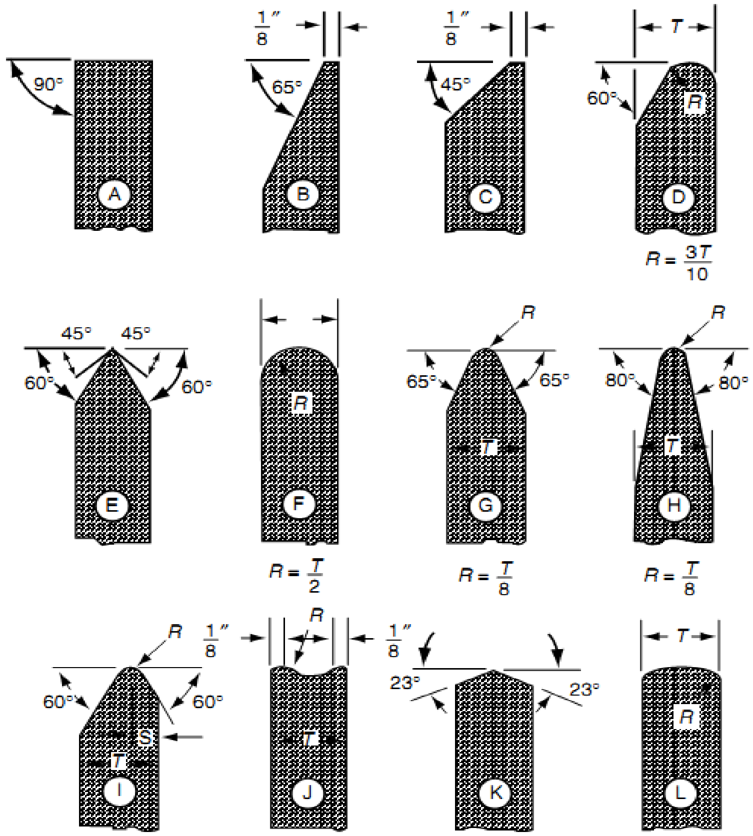


Figure 20. Standard face contours of a straight-shape grinding wheels.

- **Parameters of the grinding wheel**

To achieve the desired performance in a given application, each parameter must be carefully selected. The way the abrasive grains, bonding material, and the air gaps are structured, determines the parameters of the grinding wheel, which are

1. abrasive material,
2. **Grain size** is indicated by a number, usually from 8 (coarse) to 600 (very fine).
3. **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
4. **Grade** is the strength of the bond holding the wheel together ranging from A (soft) to Z (hard).

5. **Structure** refers to grain spacing or the manner in which the abrasive grains are distributed throughout the wheel. 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.
6. An additional number or letter(s) is sometimes used as the manufacturer's private marking to identify the grinding wheel.

1. Abrasive Materials

A **grinding machine** is a machine tool used for producing very fine finishes or making very light cuts, using an abrasive wheel made of crushed or ground abrasive grains bonded together by means of some suitable bond as the cutting device. When the moving abrasive particles contact the workpiece, each particle act as tiny cutting tools.
An abrasive is a hard material which can be used to cut or wear away other materials. Ii is extremely hard and tough, and when fractured, it forms sharp cutting edges and corners. Abrasive particles used for grinding wheels classifies grinding wheel's abrasive material in two types' viz. (a) natural abrasives and (b) artificial abrasives. Generally, for most of the purposes, natural abrasives are not used due to certain advantages of artificial (manufactured) abrasives.

Depending on the material being worked on and the desired surface finish, the most commonly used wheel's **abrasive material** can vary from aluminum oxide, silicon carbide, diamond, and cubic boron nitride (CBN), Silicon carbide or aluminium oxide, both of which are artificial (manufactured) abrasives. Silicon carbide is extremely hard but brittle and for grinding titanium. Aluminium oxide is most common of the four and preferred for most of the applications. It is slightly softer but tougher than silicon carbide, dulls more quickly, but it does not fracture easily therefore it is better suited for grinding materials of relatively high tensile strength. Diamond and CBN wheels are often made of a cheaper core with outer layer of abrasive material to make the wheel less expensive. Diamond and CBN wheels are very hard and can grind down materials such as ceramic and carbides economically. CBN wheel is well suited for grinding a variety of difficult to machine tool steels. Other considerations are same as for general grinding applications. The abrasive materials of greatest commercial importance today are listed in the table below.

Table 1: 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	C	Nonferrous, nonmetallic materials, CI, carbides, hard metals, and good finish,	green black

<96% SiC		HSS, cemented carbides, aluminum, brass, brittle materials	
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)

2. Abrasive grains

The abrasive grains are the cutting tool of a grinding wheel. They actually cut small pieces or chips off the work as the wheel rotates. A grinding wheel is designated coarse, medium, or fine according to the **size** of the individual abrasive grains making up the wheel.

The abrasive grains are classified in a screen mesh procedure. In this procedure smaller grit sizes have larger numbers and vice versa. Grain sizes used in grinding wheels typically range between 6 and 600. Grit size 6 is very coarse and size 600 is very fine. Finer grit sizes up to 1000 are used in some finishing operations.

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 **grain size** of the abrasive particle is an important parameter in determining surface finish and material removal rate. Small grit sizes produce better finishes while larger grain sizes permit larger material removal rates.

The **shape** of each grain is irregular with several sharp cutting edges. When these edges grow dull, the forces acting on the wheel tend to fracture the abrasive grains and produce new cutting edges.

The efficiency of abrasive particles depends upon

(1) Purity
(2) Uniformity in composition.
(3) Hardness: Common rule about it is that hardness of abrasive should be more that of work material.
(4) Toughness: If wheel is not tough, then abrasive particles will fracture readily and wheel wear will be excessive.
(5) Sharpness of fracture: The better cutting action is obtained by sharp edged abrasives. The natural abrasives give rounded edges and are, therefore, not efficient in cutting.

3. Bonding material

The abrasive particles (grains) in a grinding wheel are held in place by the bonding material (agent) that establishes the shape and structural integrity of the grinding wheel. The percentage of bond in the wheel determines, to a great extent, the "hardness" or "grade" of the wheel. The greater the percentage and strength of the bond, the harder the grinding wheel will be. "Hard" wheels retain the cutting grains longer, while "soft" wheels release the grains quickly. If a grinding wheel is "too hard" for the job, it will glaze because the bond prevents dulled abrasive particles from being released so new grains can be exposed for cutting. Besides controlling hardness and holding the abrasive, the bond also provides the proper safety factor at running speed. It holds the wheel together while centrifugal force is trying to tear it apart.

Desirable properties of the bond material include strength, toughness, hardness, and temperature resistance. The most common bonds used in grinding wheels include vitrified, silicate, shellac, resinoid, and rubber.

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.

4. Wheel grade

Wheel grades indicate the wheel bond strength. It is measured on a scale ranging from soft to hard. A soft wheel is one on which the cutting particles break away rapidly while a hard wheel is one on which the bond successfully opposes this breaking away of the abrasive grain. Soft wheels loose grains easily and are used for low material removal rates and grinding of hard materials. Harder grades are preferred for high productivity and grinding of relatively soft materials,

Grades of hardness

The grade of a grinding wheel designates the hardness of the bonded material. Most grinding abrasive wheels are graded according to hardness by a letter system or code ranging from A (very soft) to Z (very hard). Vitrified and silicate bonds usually range from very soft to very hard, shellac and resinoid bonds usually range from very soft to hard, and rubber bonds are limited to the medium to hard range.

5. Structure

The wheel structure indicates spacing of the abrasive grains in the wheel. It is measured on a scale that ranges from **open to dense**. Open structure means more pores and fewer grains per unit wheel volume, and vice versa. Open structure is recommended for work materials that tend to produce continuous chips, while denser structure is used for better surface finish and dimensional precision.

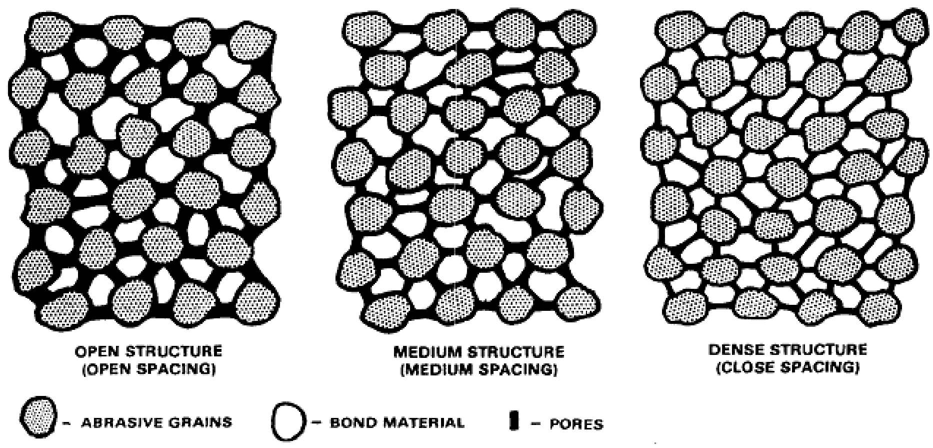


Figure 21. Grinding wheel structure

- **Grinding wheel specification**

Grinding wheels are marked with a standardized system of letters and numbers, which specifies the parameters of the grinding wheel.

Every grinding wheel is marked by the manufacturer with a stencil or a small tag. The manufacturers have worked out a standard system of markings, shown in Figure 22.

According to I.S. Specifications various elements are put in systematic manner in all wheels as follows:

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 grain : 30,36,46,54, 60

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

Very fine grain : 220,240,280,320,400500,600.

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

(3) Grade,

The following classification is employed for grade:

A—E:Very soft, G—K:Soft

L —0: Medium, P — S: Hard

T—Z: Very hard.

(4) Type of Bond.

The following notations are followed:
V — Vitrified, B — Resinoid, BF — Resinoid reinforced
R — Rubber, RF — Rubber reinforced
E — Shellac, S — Silicate., Mg — Magnesia

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.

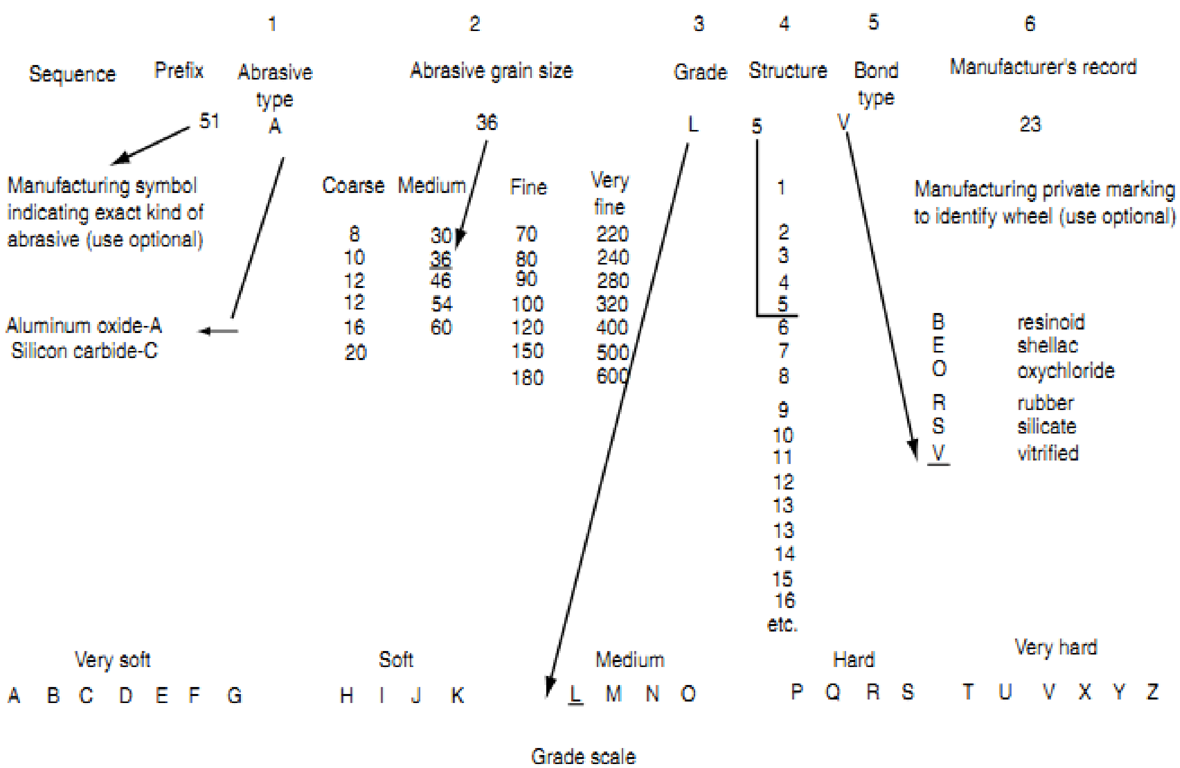


Figure 22. Standard system of marking grinding wheel

- **Selection of Grinding Wheels**

Conditions under which grinding wheels are used vary considerably, and a wheel that is satisfactory on one machine may be too hard or soft for the same operation on another machine. The different wheels are constituted by different combinations of abrasive materials, grain size, type of bond, hardness of bond, structure etc. Thus the proper selection of grinding wheels is very important for getting good results of any particular job (i.e. obtaining better finish and at the same time having more life of the wheel). In order to meet all these requirements, the various elements that influence the process must be considered. Most the material can be ground with the two wheels provided but special wheels can be obtained from grinding wheel manufacturers for special work material. The following basic factors are considered when selecting grinding wheels, though it should be understood that the rules and conditions listed are flexible and subject to occasional exceptions.

Selection mainly depends upon the following factors:

- **Constant factors.**
- **Variable factors**.

Constant k factors include

- **Work material** - It should be remembered that for grinding a soft material, hard wheel should be used and vice versa.
- **Amount and Rate of Stock Removal** - It does not influence the abrasive material but the (a) Grain size, (b) Grade, and (c) Structure. For fast removal of metal, coarse gain Size is required and vice versa. As regards grade, soft grade is used for fast removal of metal, of course at the cost of wheel life. With softer grade, the abrasive particles fall off quickly and wheel keeps on sharpening, thus removing more quantity of material. Also in order that metal may be removed at faster rate, more space is required for chip removal and hence open structure is desirable for fast removal of metal and vice versa.

- **Area of contact between work and wheel** - It mainly influences grade and to some extent grain size also. When the area of contact in grinding operation is large, total grinding pressure is distributed over a larger area and the pressure per unit area is less and hence a softer wheel is needed for it. Thus for internal grinding where arc of contact is more, softer wheel is used and for external grinding, harder wheel.

- **Condition of grinding machine** - A softer grade of wheel is used on robust and heavy machine than the light machines. If condition of grinding machine is such as to cause vibrations, harder grade is used compared to one where complete freedom from vibrations is there.

- **Finish and accuracy required on the job** - For high degree of accuracy and fine finish requirement, small sized grain wheels should be used.

Variable factors include:

- **Wheel speed and work speed** - These are the most predominant factors and about 70% of the complaints can be improved by proper selection of work and wheel speed e.g. if one gets burnt surface then speed of the wheel may be reduced. If there is excess wheel wear, it indicates that either wheel is running too slow or the work too fast. Wheel speed affects the grade to a considerable extent and for higher wheel speed, soft wheel (soft grade) should be used. Wheel speed depends upon type of grinding operation e.g. external or internal grinding or parting off operation. Work speed depends upon type of work, type of grinding and finish required. It also affects the grade, and for higher work speed it is desirable to use harder wheel and vice versa.

- **Condition of grinding** (state of the wheel spindle bearing) - By condition of grinding we mean whether the grinding is done in wet conditions or dry conditions. In dry conditions with hard wheel the heat generation is more and thus soft wheel is required and vice versa. During wet grinding, the wheel should not be partly immersed, as this would seriously throw the wheel out of balance.

- **Skill of operator** (personal factors) - An unskilled worker can't handle soft wheels and he is likely to break them. Thus unskilled worker should be allowed to work only in those conditions which require a hard wheel.

Application guidelines for grinding wheels

Proper selection of grinding wheels is very important for getting good results of any particular job i.e. obtaining better finish and at the same time having more life of the wheel. In general, the following **guidelines** are considered when selecting a GW marking:

- Choose Al_2O_3 for steels and CI;
- Choose SiC for carbides, and nonferrous metals.
- Choose CBN for hardened tool steels and certain aerospace alloys
- Choose diamond for hard abrasive materials (e.g., ceramics, cemented carbides, and glass
- Choose a hard grade with large grit size for soft and ductile materials.
- Choose a soft grade with small grit size for hard hard brittle materials.
- Choose a small grit for a good/ fine surface finish and high degree of accuracy; and a large grit (coarse gain size) for a maximum metal removal rate.
- Choose a resinoid, rubber, or shellac bond for a good surface finish, and a vitrified bond for maximum removal rate.
- Do not choose vitrified bonded wheels for cutting speeds more than 32 m/s.

- Choose softer grades for surface and internal cylindrical grinding and harder grades for external cylindrical grinding.
- Choose harder grades on non-rigid grinding machines.
- Choose softer grades and friable abrasives for heat-sensitive materials.
- To optimize surface finish and high degree of accuracy, select
  - Small grit size and dense wheel structure
  - Use higher wheel speeds (v) and lower work speeds (vw)
  - Smaller depths of cut (d) and larger wheel diameters (D) will also help
- To maximize material removal rate, select large grit size and more open wheel structure, as it has more space for chip removal
- For internal grinding use softer wheel, because When the area of contact is large, total grinding pressure is distributed over a larger area and the pressure per unit area is less and harder wheel for external grinding.

Problems often encountered

Two **problems** often encountered either by wrong selection of grinding wheel or by improper cutting conditions are wheel **glazing** and wheel **loading**.

Wheel glazing refers to the condition when the grains are worn down to the level of bond and held for too long for efficient cutting. This results due to use of a hard wheel (wheel with a strong bond strength and too fine grains). The problem can be remedied by changing the wheel and sometimes by changing the cutting conditions.

Wheel loading occurs when work piece chips are embedded in the cutting face of the wheel, thereby reducing the rate of cutting because the depth of penetration is reduced. It occurs due to too small voids and can be cured by increasing the wheel speed or using different wheel even.

Thus the **selection** of the grinding wheel for correct, Continuous and efficient cutting demands the correct selection of the type of abrasive, the size of the grains, the type of bonding agent and its strength, and the size of the voids. Further the **behavior, of the grinding wheel is affected** by Jig work piece material, cutting speed, depth of cut and the feed rate.

- **Wheel Mounting**

All grinding wheels should be mounted on the two adaptors provided; which are arranged to receive wheels having 5/8" dia. bore and up to 1/2" thickness. Note that the wheel is mounted between two flanges which are relieved on their inner surfaces so that they support the wheel only at their outer edges. This holds the wheel more securely with less pressure and with less danger of breaking. For good support, the range diameter should be about one-third of the wheel diameter.

The spindle hole in the wheel should be no more than 0.002 inch larger than the diameter of the spindle, since a loose fit will result in difficulty in centering the wheel. If the spindle hole is oversize, select another wheel of the proper size. If no others are available, fit a suitable bushing over the spindle to adapt the spindle to the hole.

Paper blotters of the proper size usually come with The grinding wheel. If the proper blotters are missing, cut them from heavy blotter paper (no more than 0.025-inch thick:) and place them between the grinding wheel and each flange. The blotters must be large enough to cover the whole area of contact between the flanges and the wheel. These blotters serve as cushions to minimize wheel breakage.

When installing the grinding wheel on the wheel spindle, the spindle clamping nut should be tightened firmly, only sufficiently to hold the wheel, but not so. tight that undue strain will be put on the wheel; as excessive clamping pressure will possibly crack the wheel and is unnecessary for driving purposes.

2. Precautions to be taken before mounting a Grinding Wheel

In the interest of satisfactory operation and safety. It is important that grinding wheels are mounted correctly on the machine and before mounting they should be examined for any defects.

Before mounting, ensure that

- a wheel has cardboard clamping rings on both sides to prevent crushing of the wheel when tightening in position,
- the steel washer, which is keyed to the adaptor is in position, this is to prevent the clamping nut unscrewing.
- a new grinding wheel should always be trued so that it will run without vibration by using a correctly and rigidly mounted diamond dressing tool. Free hand truing is most inadvisable as there is a tendency to follow any irregularities in the wheel shape.
- tool holder and method of mounting is selected appropriately

✓ **Examining the wheel for any flaw or crack**

The wheel should be first examined for any flaw or crack, which under the stresses set up due to high speed of rotation, might lead to fracture of the wheel, thus causing serious accident. For testing this, the wheel is supported with the fingers in the bore and

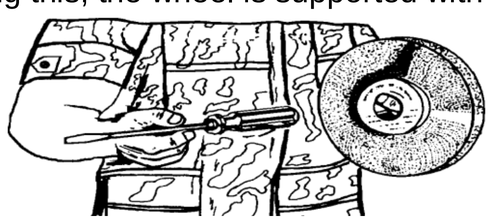


Figure 23 Checking for cracks

✓ **Examining the wheel for Out-of-balance and out-of-round of wheels**

Out-of-balance and out-of-round wheels result in vibrations and poor surface finish, faster wheel breakdown and sometimes even cause injury to the operator. For this the wheel is mounted at the centre of a perfectly straight and round spindle, the assembly is then rested on level knife-edge ways. The test should be carried out **after turning up the wheel face and mounting it on its spindle**. If there is any unbalance, wheel will come to rest with its heavy side underneath. Error is rectified by cutting some of the lead from heavy side of bush.

3. **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.

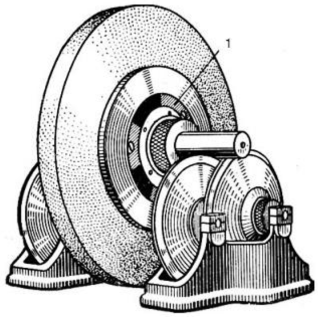


Figure 24. Revolving-disk wheel balancing stand.

- ✓ **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.

1. 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.

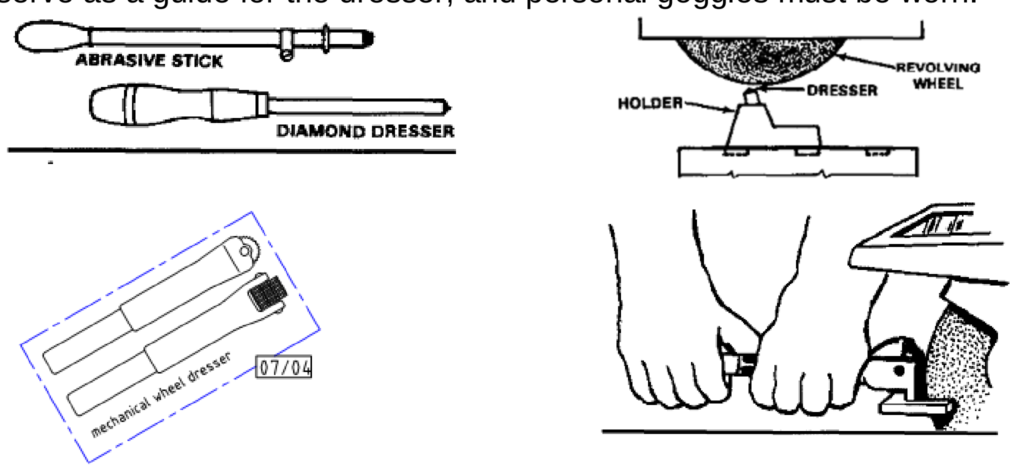


Figure 25. hand-held wheel Dressing tool

2. 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.

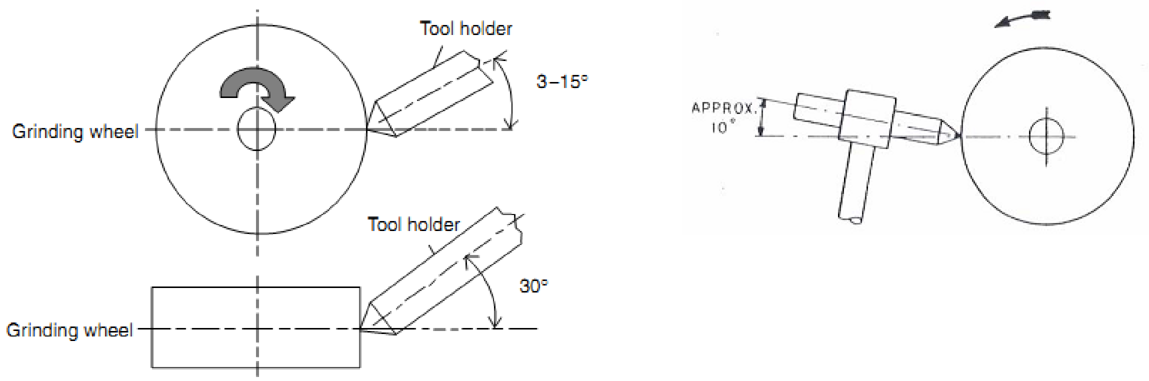


Figure 26. Diamond truing and dressing of GWs and Depth of cut

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 27 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.

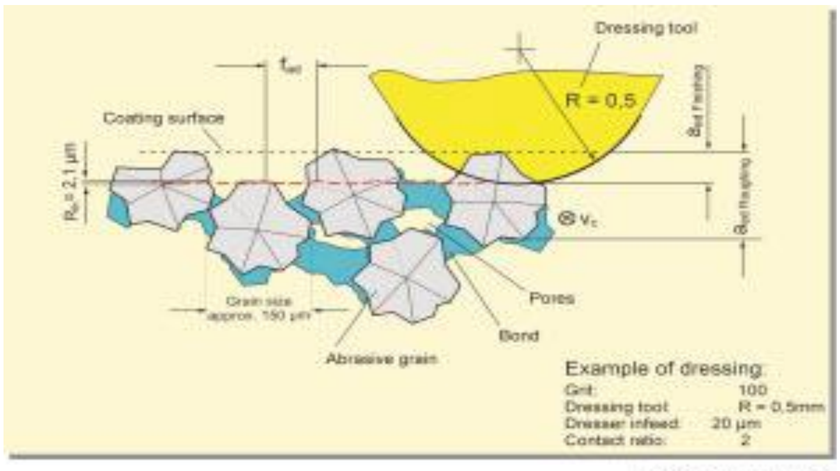


Figure 27. Size relationships in form dressing

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 2: 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 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.	The most widely used tool for dressing and truing grinding wheels 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	Used for truing operations requiring very accurately controlled, and often steeply

	diamond points, controlled cone angles and vertex radius, and the axis coinciding with that of the nib.	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 Matrix-Type Diamond Dressers	The operating surface consists 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.	For the truing of wheel surfaces 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	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

	straight and circular profile elements, kept in specific mutual locations.	adjustment, and unique versatility for handling a large variety of frequently changing profiles.

4. Methods of wheel mounting

Proper and reliable clamping of the GW on its spindle is a prime requisite, both for operator safety and to ensure high accuracy and surface finish. Figure 28 shows different methods of wheel mounting, which **depends** upon type and construction of the grinder and the shape and size of the GW. The following four items are methods and procedures for mounting grinding wheels:

Wheels of small diameter, used in chucking type internal grinding, are either seated on the spindle nose (Figure 28a), or cemented or glued on the spindle stem (Figure 28b).

GWs with small bores (all shapes except shape 5 or Cylindrical on Figure 19) are directly clamped by flanges on the spindle (Figures 28c through 28e). Rubber or leather washers of 0.5–3 mm thickness must be inserted between the flanges and the wheel to assure that the clamping pressure is evenly disturbed.

Figure 28f shows the recommended proportions of flanges relative to the wheel diameter D.

GWs of large mounting holes are mounted on an adaptor (Figure 28g), which in turn is mounted on the spindle.

Cylindrical wheels (shape 5 or Cylindrical on Figure 19) are secured on a special chuck, either by cementing with bakelite varnish, or by pouring molten sulfur, babbitt, or led into the gap between the wheel and the chuck flange (Figure 28h). The surfaces of wheel and chuck being jointed must be rough, cleaned of all dirt, and degreased.

Segmental wheels are held in their chucks either by cementing or by mechanical clamping using tapered keys (1) and screws (2 and 3, Figure 28i).

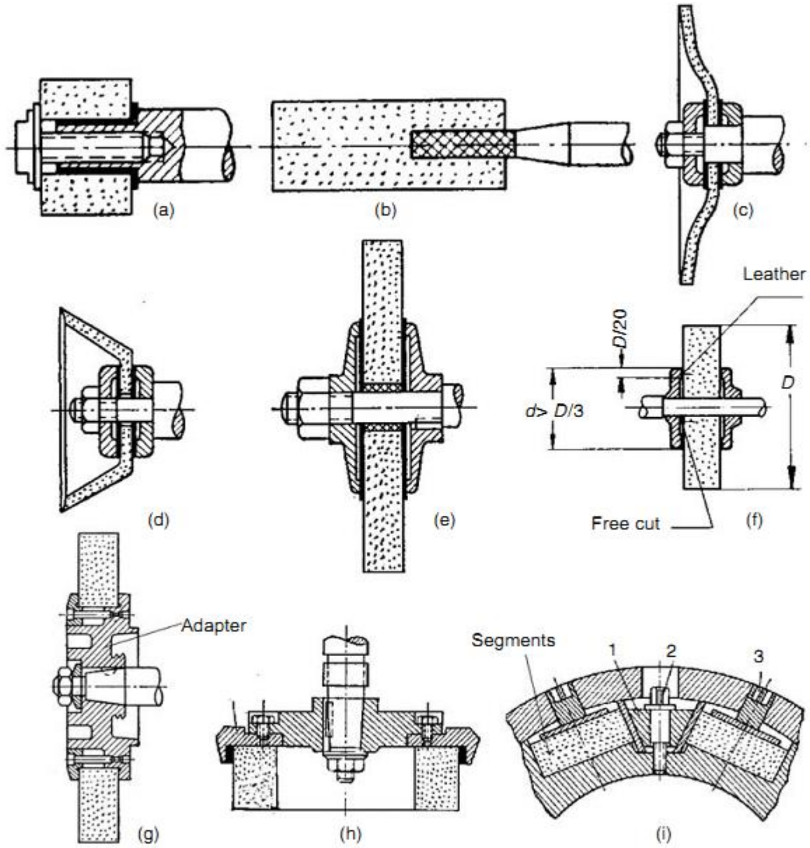


Figure 28. methods for mounting grinding wheels

Before starting operation, ensure that

1. Proper alignment in respect of coaxiality, concentricity and machine tool configuration
2. Accurate and quick locating, strong support and rigid clamping
3. Minimization of run out and deflection during cutting operation easy and quick mounting and change
4. Unobstructed (free) chip flow and cutting fluid action.
5. When wheel is mounted for the first time, it should be made it on idle for some time.
6. Safety guard should always be used, so that in case of accident operator is not injured.

Self-Check – 3	Written test

Name…………………………………………… ID………………………… Date…….

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

Test I: Short Answer Questions

1. List types of grinding wheel.
2. Define wheel dressing and what are the differences between dressing and truing?
3. Why is friability an important grit property in abrasive machining?
4. What are the commonly used materials for binding grinding wheels?
5. What are the common causes of grinding accidents?
6. Explain why the same grinding wheel might act soft or hard.
7. A soft-grade grinding wheel is generally recommended for hard materials. Explain.
8. 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

Note: **Satisfactory rating - 4 points** **Unsatisfactory - below 4 points**

You can ask you teacher for the copy of the correct answers.

Information Sheet – 4	Work holding devices and accessories

4.1. 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.

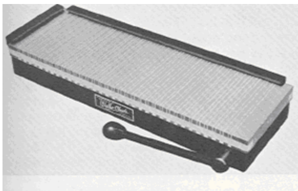


Figure 29. Magnetic chuck

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.

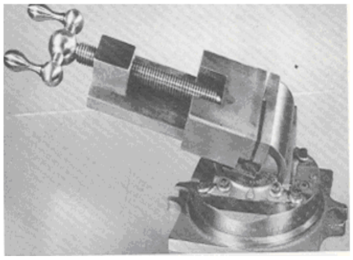


Figure 30. A universal Vise

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 31. four jaw, three jaw and Face plate

Other ways to mount work on a surface grinder:

The workpiece 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 3: 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	Used for holding bulky parts, or

	jaws, any or several of which may be used, or entirely removed, using the base plate for supporting special clamps.	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 workpiece. 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.

Grinding machine accessories

- **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.

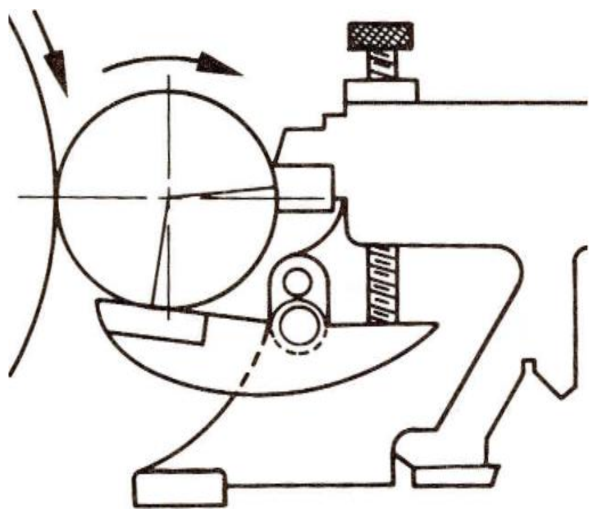


Figure 32. forming and dressing attachment

Self-Check – 4	Written test

Name…………………………………………… ID………………………… Date…….

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

Test I: Choose the best answer

1. 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

Test II: Short Answer Questions

1. List duties of operator while setting up working
2. Write the two common methods of aligning the vise with the machines?
3. What are the accessories of cylinderical grinding machines?
4. How is a workpiece controlled in centerless grinding?
5. What are the common causes of grinding accidents?

Note: **Satisfactory rating - 3 points** **Unsatisfactory - below 3 points**

Operation Sheet 1.1	Leveling the balancing fixture

Leveling the balancing fixture

1. Set the balancing fixture on a solid surface and place the ground pin across at 90 degrees, see Figure 33a. Turn the leveling screw up or down until the pin stops rolling on the fixture, somewhere away from the end. You are now rough level.
2. Mount the wheels on the flange assembly. To tighten the flange nut, gently grip the flange across the flats in a vice and rotate the wheel to snug only.
3. Put the ground pin through the wheel flange and carefully set the assembly on the fixture. Allow it to roll until it stops somewhere away from the end of the fixture. You may have to reposition several times. If the wheel will not stop rotating, you did not get your rough level close enough - adjust up or down accordingly.
4. When the wheel has settled to stop, with a pencil, mark top dead centre on the wheel, see Figure 33b.
5. Carefully pick up the wheel and flange assembly, turn it 180 degrees and set it down again. If top dead centre mark stays top dead centre, you are level. If not, adjust to compensate as per Figure 33b.
6. Start balancing by placing two screws next to the horizontal line above centre, see Position 1, Figure 33c.
   - If not balanced, add a screw to each position 2
   - If overbalanced remove the screws from position 1
   - If not balanced, add a screw to each position 3
   - If not balanced, add a screw to position 4
7. Experimentation and common sense are the only ways to determine the correct combination of screws to achieve the final weight balance for your wheels.
8. During dressing it is possible that the grinder will start vibrating again. This is because the initial balancing operation compensated for
   - Out of round wheels
   - Wheel density
   - Thickness side to side variation of the wheel
9. After dressing, the wheel will no longer be out of round so you must balance again. This step compensates for wheel density and wheel thickness variation. To rebalance, remove the wheels from the grinder, remove all weights and start balancing from the start.

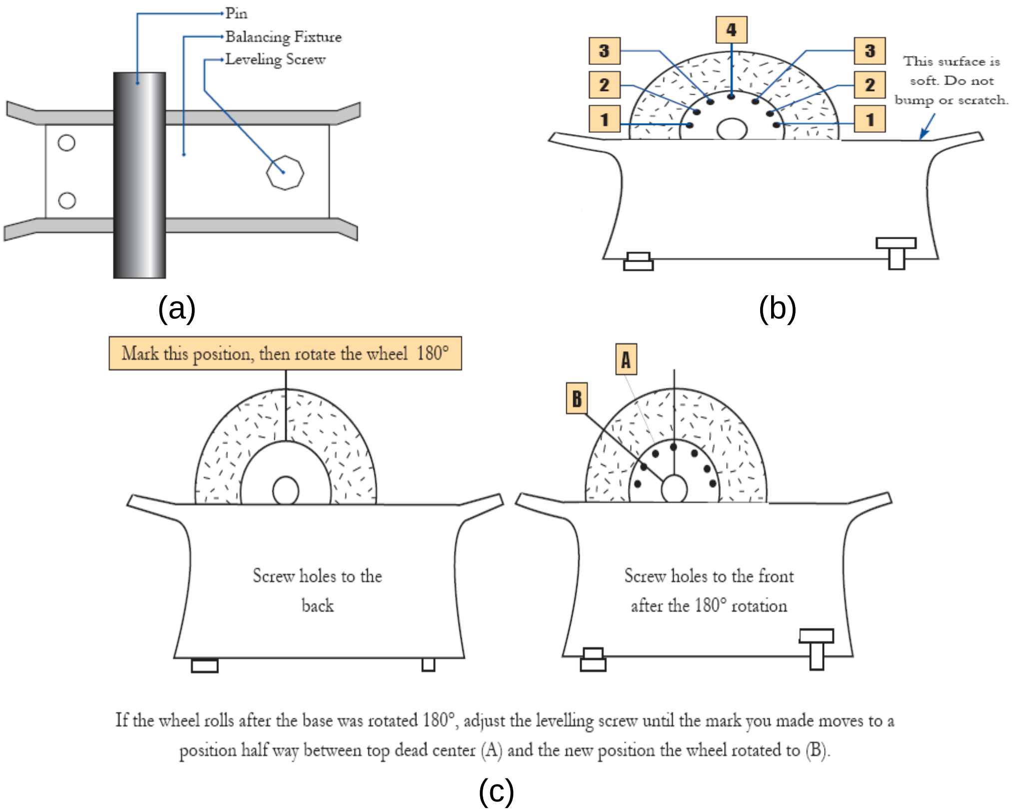


Figure 33. Leveling the balancing fixture

Two extremes may occur with grinding wheels:

- If a wheel will not balance with 7 screws on one side of centre, it is so out of balance that it should be discarded or returned to where you bought it.
- If what you have marked to be top dead centre continuously changes, then you are the rare case and you have balanced wheels! You must then dress your wheels and re-check them for balance.

NOTES

1. Occasionally, after setting the wheel on the balancing fixture, it will roll all the way to one end. This indicates that your wheels are balanced, but the fixture is not perfectly level.
2. Flange marked “R” is to be mounted on the right hand side (when facing the grinder) of the grinder, flange marked “L” on the left side of the grinder and the nut side of the flange assemblies to be on the outboard. For the right hand, turn the wheel clockwise when mounting. For left hand, turn the wheel counterclockwise when mounting.
3. Only rarely do the wheels need to be re-balanced during their lifetime provided careful dressing is practiced regularly.
4. The sides of the wheel and the flanges which clamp the wheel should be flat and bear evenly all around
5. The lead bushing should be an easy fit and no force be used.

6. The back, fixed flange should be keyed, shrunk or otherwise fixed to the spindle in order to transmit the power from the spindle to the wheel.
7. Both flanges must be relieved so that they only bear on the wheel at their rim. On no account must one of them or both should touch the sides or the wheel anywhere else. Blotting paper or rubber washer should be used between the flanges and the wheel.
8. Both flanges should be of the same **size,** the diameter preferably equal to one-half the diameter of the grinding wheel. If they are not equal in diameter, then bending stresses will be induced.

Operation Sheet – 1.2	Mounting Workpiece Grinding machine

Mounting Workpiece for Cylindrical Grinding

If cylindrical grinding is to be performed, such as grinding of workplaces mounted in the grinding may be done with the workpiece set up between centers, held in a chuck and supported by a center rest, or clamped to a faceplate as in lathe setups. Use the following methods when mounting the workpiece between centers:

1. Use a dead center in the tailstock spindle. This method is preferred because it eliminates any error caused by wear in the machine's spindle bearings. Before grinding check the accuracy and alignment of centers and correct if necessary.
2. To grind the centers, follow the procedures for grinding lathe centers
3. After the centers are accurate, align the centers by one of the methods prescribed for aligning lathe centers.
4. Position the workpiece between the centers, and use a lathe dog to revolve the workpiece.
5. Use the following methods and procedures when mounting the workpiece for concial grinding:
6. Workpieces for conical grinding can be set up in a chuck or between centers.
7. The table is swiveled to the required taper by means of the graduations on the end of the table (Figure 34.)
8. Since the table on a universal grinder is limited as to the degree that it can be swiveled, steep conical tapers are normally ground by swiveling the headstock to the angle of the taper desired (Figure 34).
9. Remember when a workpiece is to be conically ground, the workpiece axis and the grinding wheel axis must be at the same height. Otherwise, the workpiece will not be ground at the correct angle.

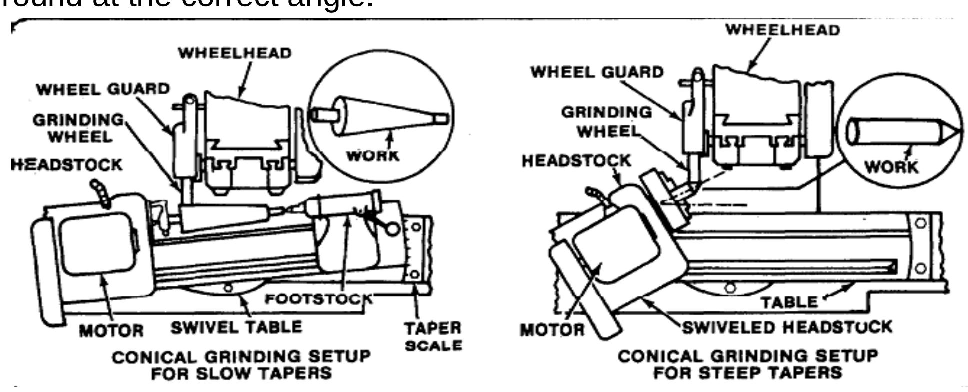


Figure 34. Conical grinding setups

Instruction Sheet	Learning Guide #32

This learning guide is developed to provide you the necessary information regarding the following **content coverage** and topics:

- Grinding machine set up and adjustment
- Surface grinding process
- Cylindrical (internal/external) grinding process

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**:

- Set up and adjust grinding machine in accordance with defined procedures.
- Perform grinding operations safely, utilizing all guards, safety procedures and personal protective clothing and equipment based on OHS and in accordance with operational standards

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the “Information Sheets”. Try to understand what are being discussed. Ask your trainer for assistance if you have hard time understanding them.
4. Accomplish the “Self-checks” which are placed following all information sheets.
5. Ask from your trainer the key to correction (key answers) or you can request your trainer to correct your work. (You are to get the key answer only after you finished answering the Self-checks).
6. If you earned a satisfactory evaluation proceed to “Operation sheets
7. Perform “the Learning activity performance test” which is placed following “Operation sheets” ,
8. If your performance is satisfactory proceed to the next learning guide,
9. If your performance is unsatisfactory, see your trainer for further instructions or go back to “Operation sheets”.

Information Sheet - 1	Perform Intermediate grinding operation

1.1. 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.

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.

- **1.2. 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:

a. **Wheel selection**. The grinding wheel for any grinding operation should be carefully chosen and the workpiece set up properly in the grinding machine.
b. **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.
c. **Wheel storage.** When not used, the wheels should be stored in a dry room and placed on their edges in racks.
d. **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.
e. **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.
f. **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.

g. 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.

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. He 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 SDFPM) / 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 = crossfeed × 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_wCSA

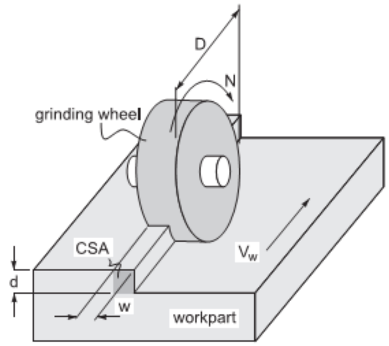


Figure 35. The geometry of surface grinding showing the cutting conditions

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

- **Lubrication and Cooling**

A lot of heat is generated at the contact of grinding wheel and the workpiece during grinding operation, majority of which is transferred to the workpiece. The use of fluids in a grinding process is necessary to cool and lubricate the wheel and workpiece as well as remove the chips produced in the grinding process. Typical workpiece materials include cast iron and mild steel don't tend to clog the grinding wheel while being processed. Other materials that tend to clog are aluminum, stainless steel, brass and some plastics.

Most grinding machines are equipped with coolant systems. The coolant is directed over the point of contact between the grinding wheel and the work. This prevents distortion of the workpiece due to uneven temperatures caused by the cutting action. In addition, coolant keeps the chips washed away from the grinding wheel and point of contact, thus permitting free cutting.

In applying the coolant, care should be taken to apply the liquid directly to the location of the grind (cutting area). This ensures the coolant reaches the material and is not deflected (blown away) by the grind wheels high speeds.

The fluid is directed to the interface between wheel and workpiece so that it can create a film of low shear strength between the wheel and the work. The fluid is supplied under pressure using special nozzles, so that air film around the wheel surface due to high speed, is penetrated. In order to prevent clogging in the wheel due to fine particles, the grinding fluid is finely filtered.

Not using the proper **grinding fluid** can result in the surface finish not being completely smooth. Of course, when grinding at high temperatures, the material tends to become weakened and is more inclined to corrode. This can also result in a loss of magnetism in materials where this is applicable.

Clear water may be used as a coolant, but various compounds containing alkali are usually added to improve its lubricating quality and prevent rusting of the machine and workpiece. An inexpensive coolant often used for all metals, except aluminum, consists of a solution of approximately 1/4 pound of sodium carbonate (sal soda) dissolved in 1 gallon of water. Another good coolant is made by dissolving soluble cutting oil in water. For grinding aluminum and its alloys, a clear water coolant will produce fairly good results. Grinding fluids containing sulfur or chlorine additives help in reducing the cutting force and improving the surface finish and increasing the life of the grinding wheel. Usually water based emulsions and grinding oils in ample quantity (15-20 liters/mm for normal medium sized grinding machine) are used for this purpose. There are **different types of coolants** that are used depending on the material that is being worked on; the most common grinding fluids are:

- Water-soluble chemical fluids,
- Water-soluble oils,
- Synthetic oils, and
- Petroleum-based oils.

Lubrication

Keep slides and machined surfaces clear of grinding dust and lightly oil daily. Oil weekly, all moving parts provided with oil nipples with the oil gun provided. Use any good quality light machine oil.

NOTE: Motor bearings are lubricated and sealed for life and require no attention.

Self-Check – 2	Written test

Name…………………………………………… ID………………………… Date…….

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

Test I: Short Answer Questions

1. List duties of operator while setting up working
2. Write down all the safety requirements for grinding machine operation.
3. Write three examples of Hazards parts of machines? (3points)
4. Why should a grinding fluid be used in very copious quantities when performing wet grinding?
5. What are the common causes of grinding accidents?

Note: **Satisfactory rating - 3 points** **Unsatisfactory - below 3 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Operation Sheet 1	Grinding Machines Operations

Grinding Machines Operations Procedure

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

- **Sequence of operations for surface grinding**

The following sequence is provided as a step-by-step example of a typical surface grinding operation.

- ✓ Adjust the surface grinding machine so that grinding head and worktable are absolutely parallel.
- ✓ Place a grinding wheel of the proper grain, grade, structure, and bond on the wheel spindle.
- ✓ Place the guard over the wheel and check security of all adjustable members of the grinding machine for rigidity and lack of backlash.
- ✓ True and dress the grinding wheel.
- ✓ Mount the workpiece to the worktable (magnetic chuck). Make sure the surface to be ground is parallel to the worktable and the grinding wheel.
- ✓ Adjust wheel speed, work speed, and work feed.
- ✓ Move the chuck lever to the position that energizes the magnetic field.
- ✓ Set the table stop dogs so the sliding table will move the work clear of the wheel at each end of the stroke.
- ✓ Set the longitudinal traverse speed of the worktable.
- ✓ Set the cross traverse mechanism so the table moves under the wheel a distance slightly less than the width of the wheel after each pass.
- ✓ Start the spindle motor, let the machine run for a few minutes, and then dress the wheel.
- ✓ Feed the moving wheel down until it just touches the work surface; then use the manual cross traverse hand wheel to move the work clear of the wheel. Set the graduated feed collar on zero to keep track of how much you feed the wheel into the work.
- ✓ Feed the wheel down and engage the longitudinal power traverse. Use the cross traverse hand wheel to bring the grinding wheel into contact with the edge of the work piece.
- ✓ Engage the power cross traverse and let the wheel grind across the surface of the work piece.
- ✓ Proceed with grinding, adjusting depth of cut as necessary.
- ✓ Carefully note the cutting action to decide if you need to adjust the wheel speed or the work speed. Stop the longitudinal and cross traverses and check the work piece.

- ✓ Check for accuracy between each cut and determine that the workpiece is square and the wheel is not out of alignment. If it is necessary to use more than one grinding wheel to complete the grinding, each wheel should be trued and dressed after it is mounted.

- Sequence of operations for Plain Cylindrical Grinding

The step-by-step procedure for grinding a straight shaft is given below. The shaft has been roughly turned prior to grinding.

- Check and grind headstock and tailstock centers if necessary.
- Check drilled centers of workpiece for accuracy.
- Place a grinding wheel of the proper grain, grade, structure, and bond on the wheel spindle.
- Place wheel guards in position to cover the wheel adequately.
- Set the proper wheel speed on grinding machine.
- Place the diamond dresser and holder on the machine table and true and dress the grinding wheel.
- If two or more grinding wheels of different grain size are used during the grinding procedure, each wheel should be dressed and trued as soon as it is mounted in the grinding machine.
- Mount the headstock and footstock on the table.
- Attach the proper size drive dog on the headstock end of the workpiece.
- Mount the workpiece between headstock and tailstock centers. Use lubricant (oil and white lead mixture) on tailstock center. Make sure centers fit drill center holes correctly with no play.
- Set the proper rotational work speed on the wheel head. The general range of work speed for cylindrical grinding is 60 to 100 surface feet per minute (SFPM). Heavy rough grinding is sometimes performed at work speeds as low as 20 or 30 SFPM. Soft metals such as aluminum are sometimes ground at speeds up to 200 SFPM.
- Position the table trip dogs to allow minimum table traverse. The wheel should overlap each end of the workpiece not more than one-half the wheel width to assure a uniform straight cut over the length of the workpiece.
- Calculate the table traverse feed using this formula.
  - ✓ TT = (WW X FF X WRPM) + 12
  - ✓ Where TT = Table travel in feet per minute
  - ✓ WW = Width of wheel
  - ✓ FF = Fraction of finish
    - ➢ for annealed steels is 1/2 for rough grinding and 1/6 for finishing;
    - ➢ for hardened steels the rate is ¼ for rough grinding and 1/8 for finishing
  - ✓ WRPM = Revolutions per minute of workpiece

- ✓ 12 = Constant (inches per foot)

For example: a l-inch-wide wheel is used to rough grind a hardened steel cylinder with a work RPM of 300.

Table travel = (1 x 1/4 x 300) ÷ 12 = (75) ÷ 12 = 6.25 FPM

- After the calculations have been completed, set the machine for the proper traverse rate, turn on the table traverse power feed, and grind the workpiece.
- Check the workpiece size often during cutting with micrometer calipers. Check the tailstock center often and readjust if expansion in the workpiece has caused excessive pressure against the drilled center in the workpiece.
- The finishing cut should be slight, never greater than 0.001 inch, and taken with a fine feed and a fine grain wheel.
- Sequence of operations for Internal grinding

The following step-by-step procedure for grinding the bore of a bushing is outlined below as an example.

- ✓ Bolt internal grinding attachment to the wheel head on the universal tool and cutter grinder.
- ✓ Set up the workpiece in an independent chuck and check and adjust its alignment, to rotate in the direction opposite that of the grinding wheel.
- ✓ Mount the internal grinding attachment to the wheel head and adjust its position so that the grinding wheel is centered vertically with the mounted workpiece.
- ✓ True and dress the grinding wheel.
- ✓ If two or more grinding wheels are used to complete internal grinding, true each wheel after mounting it to the spindle of the internal grinding attachment.
- ✓ Set the proper wheel speed on the grinding machine by adjusting the pulleys and belts connecting the wheel spindle to the drive motor shaft.
- ✓ The RPM is increased by placing a large pulley on the motor and a small pulley on the attachment.
- ✓ Set the proper rotational work feed. The speed should be 60 to 100 surface feet per minute (SFPM).
- ✓ Be sure sufficient clearance is allowed when setting the traversing speed so that the grinding wheel will not strike any part of the workpiece or setup when the wheel is fed into and retracted from the workpiece.

Instruction Sheet	Learning Guide #33

This learning guide is developed to provide you the necessary information regarding the following **content coverage** and topics:

- Conformance checking techniques, tools and equipment.
- Tolerances and surface finish
  - ✓ Grade of tolerance
  - ✓ Quality of finishing
- Checking deviations

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 using standard techniques, tools and equipment
- Determine required grade of tolerance based on drawing and work standards

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the "Information Sheets". Try to understand what are being discussed. Ask your trainer for assistance if you have hard time understanding them.
4. Accomplish the "Self-checks" which are placed following all information sheets.
5. Ask from your trainer the key to correction (key answers) or you can request your trainer to correct your work. (You are to get the key answer only after you finished answering the Self-checks).
6. If you earned a satisfactory evaluation proceed to "Operation sheets
7. Perform "the Learning activity performance test" which is placed following "Operation sheets" ,
8. If your performance is satisfactory proceed to the next learning guide,
9. If your performance is unsatisfactory, see your trainer for further instructions or go back to "Operation sheets".

Information Sheet -1	Quality assure components in conformance to specifications

Introduction

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.

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.

Tolerances and Surface Finishes

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:

50 H8	50 H8 $\left(\begin{matrix}50.039\\50.000\end{matrix}\right)$	$\begin{matrix}50.039\\50.000\end{matrix}$ (50 H8)
(a) PREFERRED	(b)	(c)

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 4: The fundamental tolerances of grades

Table 3.3. Fundamental tolerances of grades IT01, IT0 and IT1 to IT16, according to IS : 919 (Part I) – 1993.

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 To and inc.	1 3	0.3	0.5	0.8	1.2	2	3	4	6	10	14	25	40	60	100	140	250	400	600
Over To and inc.	3 6	0.4	0.6	1	1.5	2.5	4	5	8	12	18	30	48	75	120	180	300	480	750
Over To and inc.	6 10	0.4	0.6	1	1.5	2.5	4	6	9	15	22	36	58	90	150	220	360	580	900
Over To and inc.	10 18	0.5	0.8	1.2	2	3	5	8	11	18	27	43	70	110	180	270	430	700	1100
Over To and inc.	18 30	0.6	1	1.5	2.5	4	6	9	13	21	33	52	84	130	210	330	520	840	1300
Over To and inc.	30 50	0.6	1	1.5	2.5	4	7	11	16	25	39	62	100	160	250	390	620	1000	1600
Over To and inc.	50 80	0.8	1.2	2	3	5	8	13	19	30	46	74	120	190	300	460	740	1200	1900
Over To and inc.	80 120	1	1.5	2.5	4	6	10	15	22	35	54	87	140	220	350	540	870	1400	2200
Over To and inc.	120 180	1.2	2	3.5	5	8	12	18	25	40	63	100	160	250	400	630	1000	1600	2500
Over To and inc.	180 250	2	3	4.5	7	10	14	20	29	46	72	115	185	290	460	720	1150	1850	2900
Over To and inc.	250 315	2.5	4	6	8	12	16	23	32	52	81	130	210	320	520	810	1300	2100	3200
Over To and inc.	315 400	3	5	7	9	13	18	25	36	57	89	140	230	360	570	890	1400	2300	3800
Over To and inc.	400 500	4	6	8	10	15	20	27	40	63	97	155	250	400	630	970	1550	2500	4000

Surface finishes

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 Workpiece 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 5: 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 6: 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.

Self-Check – 1	Written test

Name…………………………………………… ID……………………… Date…….

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

Test I: Choose the best answer

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

Test II: Short Answer Questions

1. Define the following terms
   a) Tolerance
   b) Actual size
   c) Allowance
   d) Deviations
2. What is MMC?
3. What is the term for the theoretical size of a feature?
4. 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?

Note: **Satisfactory rating - 3 points** **Unsatisfactory - below 3 points**

You can ask you teacher for the copy of the correct answers.

Operation sheet – 1	Quality assure components in conformance to specifications

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	Grinding Engineering / Workshop Steel Parallels (Block)

Operation title: **Grinding Engineering / Workshop Steel Parallels (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

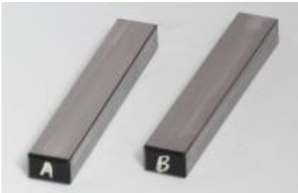
Precautions: - Wear protective clothing

Tools and equipment:

- Vernier caliper
- Students Guide

- Goggles

Working drawing:



Procedures for Grinding Engineering Parallels (workshop steel parallel 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 Test	Demonstration

Name……………………………… ID………

Date……..

Time started: ________________________ Time finished: ________________

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within **1** hour. The project is expected from each student to do it.

During your work: You can ask all the necessary tools and equipment

Lap Test Title: Produce Tool Shanks for Milling Machines

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

Specifications: Tool Shank (Face Mill Arbor) for Milling Machines, made from **steel**, ground and finished to a precise smooth surface finish.

Use: For holding face mill cutters and cutters with radial driving slot DIN 1880

Description of Technical data and Standard Quality:

- Chuck body fine balanced G2.5 at 22.000 rpm
- All functional surfaces fine machined
- Taper SK40 and Taper tolerance AT3
- Include 4 additional tapping holes to receive tightening bolt
- Clamping diameter Ø D1 (milling cutter hole size in mm): 16 mm (DIN 2079), 22mm, 27mm
- Length of Clamping Diameter (Width of milling cutter in mm) L: 10mm, 12mm, 14mm, **17 mm**, 20mm
- Possible exceeding clamping diameter Ø D2 (in mm): short **32mm, 36 mm**

Quality criteria: - The article must be made to the given dimensional accuracy so that it fit to the milling Machine's spindle taper. All the sides are chamfered.

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

Material: previously machined work piece (Tool Shanks for Milling Machines) on lathe machine to rough dimensions, leaving a few millimeters to allow the rest to be ground and then hardened to 55 - 60 HRC

Tools / Equipment Needed:

- Cylindrical / Universal Grinding machine with accessories
- Measuring instrument: Vernier caliper, micrometer

Precautions: - Wear protective clothing

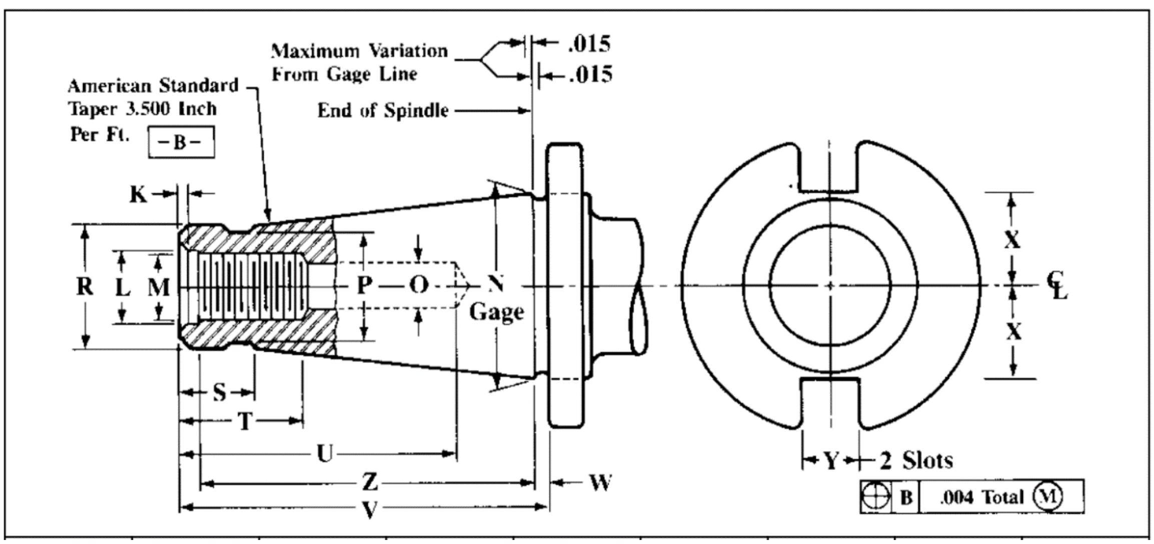
Task Objectives / Demands: in accomplishing activities required for this project the student will be able to: (**During your work follow these steps:**)

1. Determine the safety requirements and measures in operating the grinding machine correctly.
2. Determine a required grade of tolerance based on drawing and work standards

3. Perform basic mathematical operations
4. Prepare tools and equipment, supplies and materials for operation;
5. Put on oil or grease to the countersunk holes at both ends of the workpiece.
6. Mount work piece between centers on the cylindrical grinding machine; and Clamp the workpiece in the grinding dog which is connected with the drive plate
7. Set the appropriate spindle speed and feed.

   RPM=$\frac{CSx1000}{\pi D}$
8. Start the machine and then adjust and position the grinding wheel slowly along cylindrical workpiece; putting on a mechanical blue on the surface of work to be ground; Just touches it.
9. Set the collar at zero point and Turn on the coolant.
10. Perform Grind work piece with appropriate spindle speed, feed and feed rate; Set a roughing cut about 0.015mm and engage the automatic feed.
11. After a roughing cut, check the workpiece and take two or more finishing cuts.
12. Then, the finishing is applied, machining a chamfer along the edges to remove any burrs or sharpened edges
13. Demonstrate the all procedures to grind the Tool Shanks for Milling Machines correctly.
14. Establishing Standards and Methods for Measuring Conformance
15. Check work piece diameter and length for conformance of the machined part
16. Determination of Whether the Conformance Matches the Standard, and Taking Corrective Action

Technical drawing



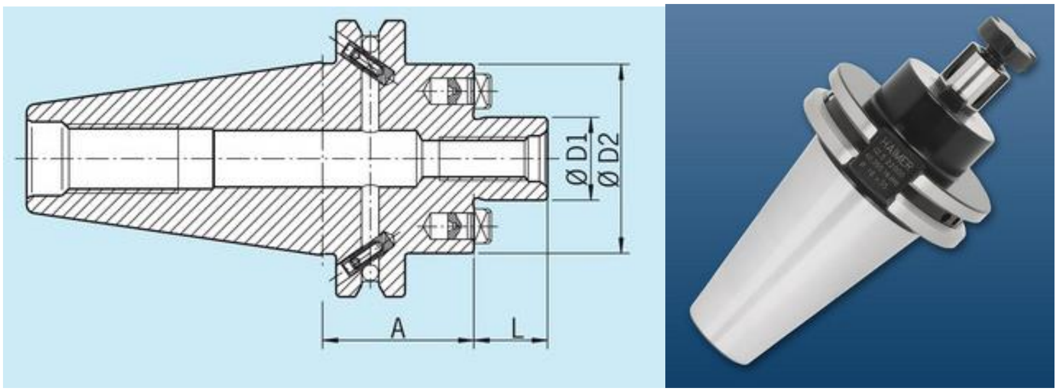


Figure 36: Tool Shanks for Milling Machines (Source: ANSI B5.18-1972)

Table 7: Essential Dimensions of Tool Shanks for Milling Machines (ANSI B5.18-1972 (R1998). All dimensions are given in inches.

Size No.	Gage Dia.of Taper *N*	Tap Drill Size for Draw-in Thread *O*	Dia.of Neck *P*	Size of Thread for Draw-in Bolt UNC-2B *M*	Pilot Dia. *R*	Length of Pilot *S*	Minimum Length of Usable Thread *T*	Minimum Depth of Clearance Hole *U*
30	1.250	0.422 0.432	0.66 0.65	0.500–13	0.675 0.670	0.81	1.00	2.00
40	1.750	0.531 0.541	0.94 0.93	0.625–11	0.987 0.980	1.00	1.12	2.25
45	2.250	0.656 0.666	1.19 1.18	0.750–10	1.268 1.260	1.00	1.50	2.75
50	2.750	0.875 0.885	1.50 1.49	1.000–8	1.550 1.540	1.00	1.75	3.50
60	4.250	1.109 1.119	2.28 2.27	1.250–7	2.360 2.350	1.75	2.25	4.25

Size. No.	Distance from Rear of Flange to End of Arbor *V*	Clearance of Flange from Gage Diameter *W*	Tool Shank Centerline to Driving Slot *X*	Width of Driving Slot *Y*	Distance from Gage Line to Bottom of C'bore *Z*	Depth of 60° Center *K*	Diameter of C'bore *L*
30	2.75	0.045 0.075	0.640 0.625	0.635 0.645	2.50	0.05 0.07	0.525 0.530
40	3.75	0.045 0.075	0.890 0.875	0.635 0.645	3.50	0.05 0.07	0.650 0.655
45	4.38	0.105 0.135	1.140 1.125	0.760 0.770	4.06	0.05 0.07	0.775 0.780
50	5.12	0.105 0.135	1.390 1.375	1.010 1.020	4.75	0.05 0.12	1.025 1.030
60	8.25	0.105 0.135	2.400 2.385	1.010 1.020	7.81	0.05 0.12	1.307 1.312

Tolerances: Two digit decimal dimensions ± 0.010 inch unless otherwise specified.
M—Permissible for Class 2B "NoGo" gage to enter five threads before interference.
N—Taper tolerance on rate of taper to be 0.001 inch per foot applied only in direction which increases rate of taper.

Y—Centrality of drive slot with axis of taper shank 0.004 inch at maximum material condition. (0.004 inch total indicator variation)

For example: if you select Size No. = 40; the technical data will be

- Gage Dia. of Taper N: 1.750
- Tap Drill Size for Draw-in Thread O: 0.531
  0.541
- Dia. of Neck P: 0.94
  0.93
- Size of Thread for Draw-in Bolt UNC-2B M: 0.625–11
- Pilot Dia. R: 0.987
  0.980
- Length of Pilot S: 1.00
- Minimum Length of Usable Thread T: 1.12
- Minimum Depth of Clearance Hole U: 2.25
- Distance from Rear of Flange to End of Arbor V: 3.75
- Clearance of Flange from Gage Diameter W: 0.045
  0.075
- Tool Shank Centerline to Driving Slot X: 0.890
  0.875
- Width of Driving Slot Y: 0.635
  0.645
- Distance from Gage Line to Bottom of C'bore Z: 3.50
- Depth of 60° Center K: 0.05
  0.07
- Diameter of C'bore L: 0.650
  0.655

Tapers for Machine Tool Spindles. —Various standard tapers have been used for the taper holes in the spindles of machine tools, such as drilling machines, lathes, milling machines, or other types requiring a taper hole for receiving either the shank of a cutter, an arbor, a center, or any tool or accessory requiring a tapering seat.

Milling machine spindles formerly had Brown & Sharpe tapers in most cases. In many cases there are a number of different lengths of Brown & Sharpe taper sockets corresponding to the same number of taper; all these tapers, however, are of the same diameter at the small end.

In 1927, the milling machine manufacturers of the National Machine Tool Builders' Association adopted a standard taper of 3 ½ inches per foot. This comparatively steep taper has the advantage of insuring instant release of arbors or adapters. Taper per foot represents inches of taper per foot of length and can be checked with Sine-bar.

Table 8: National Machine Tool Builders' Association Tapers (Standard taper of 3 ½ inches per foot)

Taper Number	Large End Diameter
30	1 ¼
40	1 ¾
50	2 ¾
60	4 ¼

The **British Standard** for milling machine spindles is also 3 ½ inches taper per foot and includes these large end diameters: 1 3⁄8 inches, 1 ¾ inches, 2 ¾ inches, and 3 ¼ inches. This Standard contains dimensions for self-holding and self-releasing tapers. The table of Tapers per Foot and Corresponding Angles shows that the included angle for a taper of inches per foot in degrees or degrees, minutes, and second, from the calculator.

Table 9: Tapers per Foot and Corresponding Angles

Tapers per Foot	Included angle		Angle with Center Line
1 ¼	6.260490	5° 57' 47"	2° 58' 53"
1 3⁄8	6.855367	6° 33' 29"	3° 16' 44"
1 ¾	8.637654	8° 20' 27"	4° 10' 14"
2 ¾	13.662012	13° 4' 24"	6° 32' 12"
3 ¼	16.009458	15° 25' 26"	7° 42' 43"
3 ½	**17.178253**	**16° 35' 39"**	**8° 17' 50"**
4 ¼	20.662210	20° 5' 3"	10° 2' 31"

List of Reference Materials

Book:

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.

WEB ADDRESSES

1. ISO 9000:2005 Quality Management System – Fundamentals and Vocabulary
2. http://www.qualitygurus.com/courses/mod/forum/discuss.php?d=1557
3. http://www.iitg.ac.in/spal/Methods%20of%20mounting%20of%20jobs%20and%20cutting%20tools.ppt
4. http://www.iitb.ac.in/safety/sites/default/files/Machine%20Safety_0_0.pdf)
5. https://www.fda.gov/media/109408/download
6. https://www.flexiblemachining.com/pdf/quality_policy.pdf

The trainers who developed the learning guide

No	Name	Qualification	Region	E-mail
1	Wakweya Tolera	A	Oromia	Wakweya.tolera@yahoo.com
2	Mohammed Abdela	A	Dire Dewa	mahammedabdella49@gmail.com
3	Waliyi Bena	A	Oromia	waliyibena@gmail.com
4	Elias Zemenu	A	Somali	Elijahze26@gmail.com
5	Gurmu Mulatu	A	Adis Ababa	gurmumuulaatuu@gmail.com
6	Muluneh Negussie	B	Amhara	Muluneh3000@gmail.com
7	Teshome W/Yuhanis	A	SNNPR	Tesho1921@gmail.com
8	Solomon Aderaw	B	Amhara	Solo19@gmail.com