MANUFACTURING PROCESSES

Grinding

GRINDING

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Introduction

- ***Grinding*** is a ***material removal process*** accomplished by ***abrasive particles*** that are contained in a ***bonded grinding wheel*** rotating at very high surface speeds.

- The grinding wheel is usually disk-shaped, and is precisely balanced for high rotational speeds.

Introduction

- Grinding is ***similar*** to the ***milling process***.

- Cutting occurs on either the periphery or the face of the grinding wheel, similar to peripheral and face milling.

- The rotating grinding wheel consists of ***many cutting teeth*** (the ***abrasive particles***), and the work is fed relative to the wheel to accomplish material removal.

Introduction

- Regardless of the size of the grain, only a small percentage ***(2 to 5%)*** of the surface of the grain is ***operative at any one time.***

- That is, the ***depth of cut*** for an individual grain (the actual feed per grit) with respect to the grain diameter ***is very small***.

- Thus the ***chips are small***.

Introduction

- ***Chips flying in the air*** from a grinding process often have sufficient ***heat energy to burn or melt*** in the atmosphere.

- ***Sparks observed*** during grinding steel with no cutting fluid ***are really burning chips***

GRINDING vs Milling

- There are significant differences between grinding and milling:
  - the ***abrasive grains*** in the wheel are ***much smaller*** and ***more numerous*** than the teeth on a milling cutter
  - ***cutting speeds*** in grinding are ***much higher*** than in milling
  - the ***abrasive grits*** in a grinding wheel are ***randomly oriented*** and possess on average a very ***high negative rake angle***

GRINDING

– a grinding wheel is ***self-sharpening***—as the wheel wears, the abrasive particles become dull and either ***fracture to create fresh cutting edges*** or are ***pulled out of the surface*** of the wheel to expose new grains.

Parameters of a grinding wheel

Parameters of a grinding wheel

- A ***grinding wheel*** consists of ***abrasive particles*** and ***bonding material***.

- The ***bonding material holds the particles in place*** and establishes the shape and structure of the wheel.

Parameters of a grinding wheel

- These two ingredients and the way they are fabricated determine the five basic parameters of a grinding wheel:

  (1) abrasive material,

  (2) grain size,

  (3) bonding material,

  (4) wheel structure,

  (5) wheel grade.

(1) ABRASIVE MATERIAL

- Different abrasive materials are appropriate for grinding different work materials.

- General properties of an abrasive material used in grinding wheels include ***high hardness, wear resistance, toughness,*** and ***friability.***

- ***Friability*** refers to the ***capacity*** of the abrasive material ***to fracture*** when the cutting edge of the grain becomes dull, thereby ***exposing a new sharp edge***.

(1) ABRASIVE MATERIAL

- High friability means that the grains will fracture with relative ease during grinding.
- In effect, this allows for sharp cutting points to be developed, leading to more effective grinding.
- If, on the other hand, the grains do not fracture easily, the cutting points will become dull and grinding will become in-efficient; this situation will then lead to unacceptable temperature rise and adversely affecting surface quality.

(1) ABRASIVE MATERIAL

- Most commonly used Abrasive grains are
  - ***Aluminum oxide***
  - ***Silicon carbide***
  - ***Diamond Grains***
  - ***Boron Carbibe and Cubic Boron Nitride***

(2) GRAIN SIZE

- ***Small grit*** sizes produce ***better finishes***, whereas ***larger grain*** sizes permit ***larger material removal*** rates.

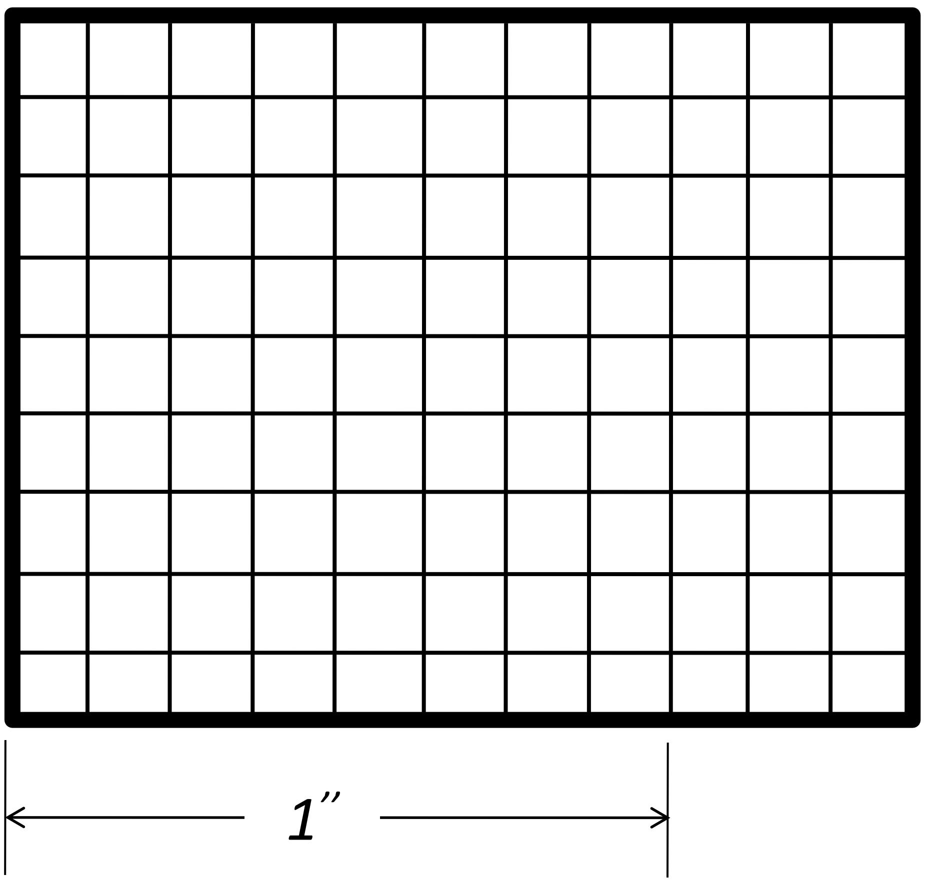
- ***Harder*** work materials require ***smaller grain sizes*** to cut effectively, whereas ***softer*** materials require ***larger grit sizes***.

(2) GRAIN SIZE

- Grain sizes used in grinding wheels typically range between ***8*** and ***250.***

- Grit size ***8*** is ***very coarse*** and size ***250*** is ***very fine***.

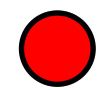
(2) GRAIN SIZE



8 openings

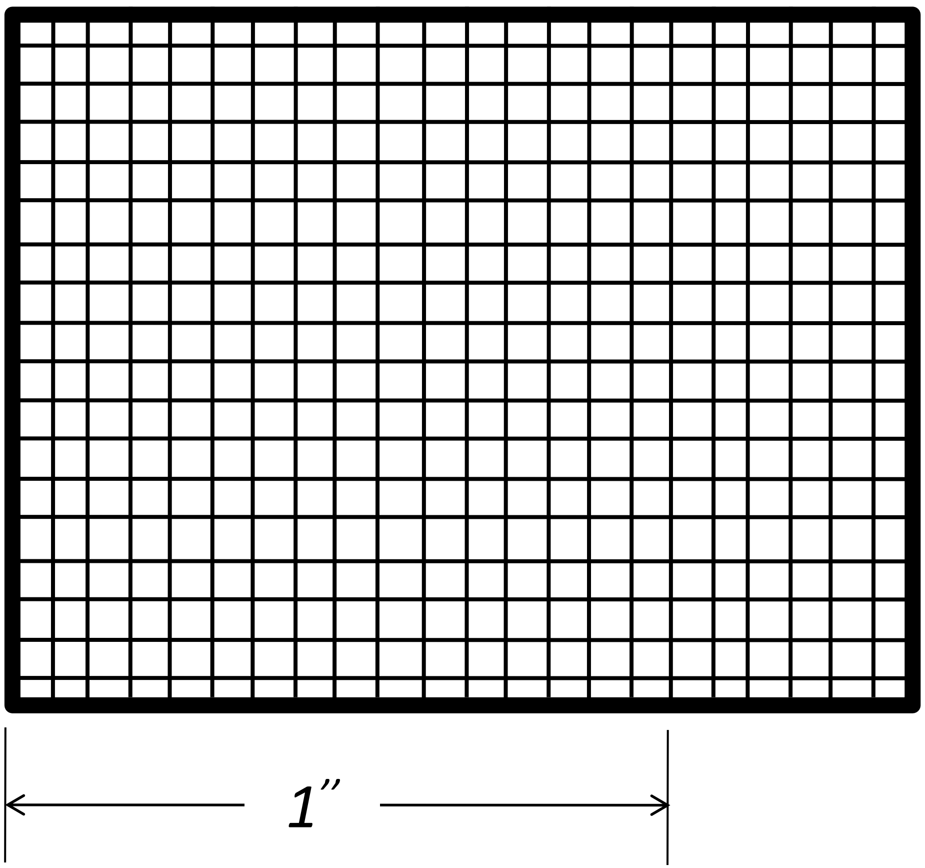
Mesh/Screen/Sieve Size = 8

Grain/Grit Size = 8



Particle Size that would pass through Mesh

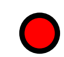
(2) GRAIN SIZE



16 openings

Mesh/Screen/Sieve Size = 16

Grain/Grit Size = 16



Particle Size that would pass through Mesh

(3) BONDING MATERIAL

- The bonding material ***holds*** the ***abrasive grains*** and establishes the shape and structural integrity of the grinding wheel.

- Desirable properties of the bond material include
  - ***strength,***
  - ***toughness,***
  - ***hardness, and***
  - ***temperature resistance.***

(3) BONDING MATERIAL

- The bonding material must be:-
  - ***able to withstand the centrifugal forces and high temperatures experienced by the grinding wheel***
  - ***resist shattering in shock loading of the wheel,***
  - ***hold the abrasive grains rigidly in place***

  to accomplish the cutting action.

(3) BONDING MATERIAL

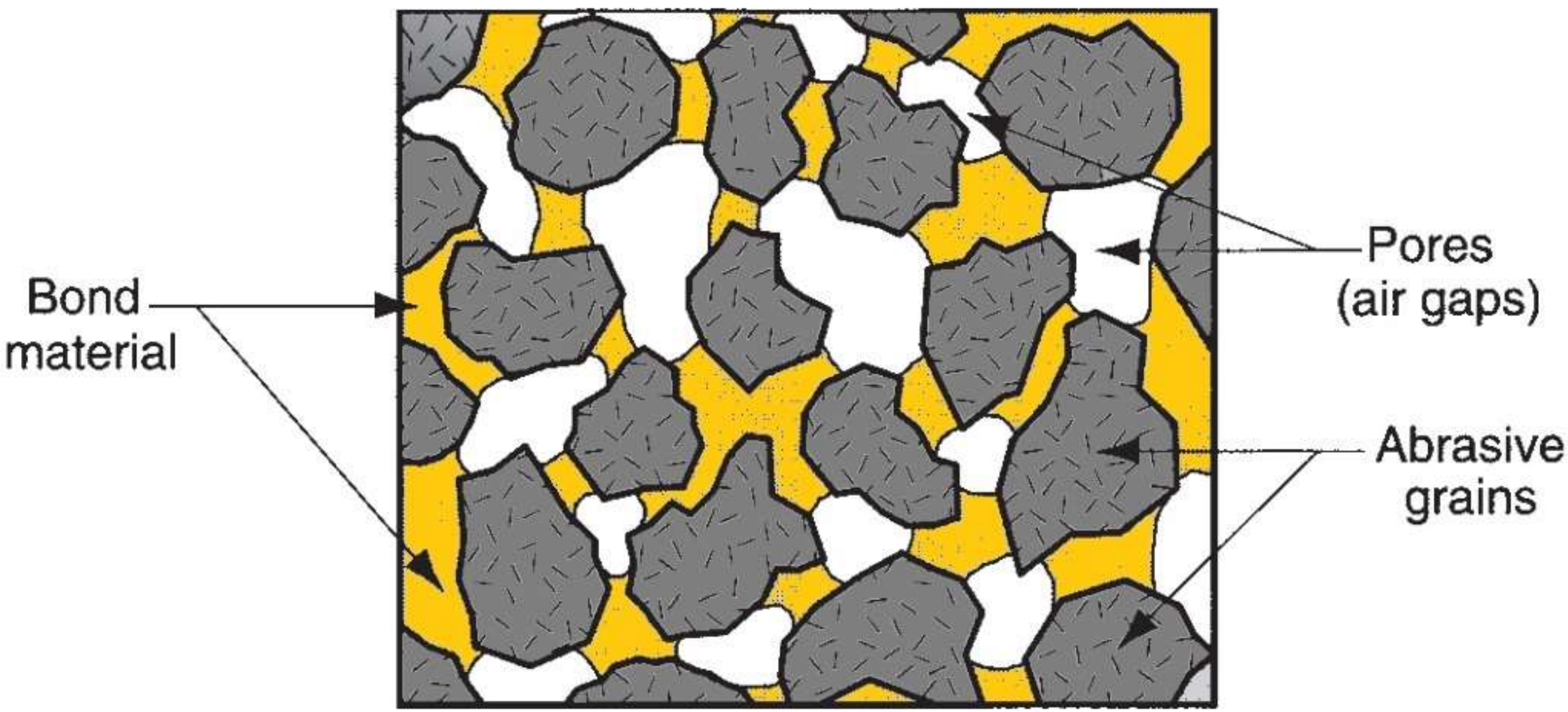
- Commonly used bond materials are
  - ***Vitrified bond***
  - ***resinoid***
  - ***rubber***
  - ***shellac and silicate bonds***
- Vitrified bond is the most common bond material .

(4) WHEEL STRUCTURE

- Wheel structure refers to the ***relative spacing*** of the ***abrasive grains*** in the wheel.

- In addition to the abrasive grains and bond material, grinding wheels contain ***air gaps*** or pores, as illustrated in Figure.

(4) WHEEL STRUCTURE



(4) WHEEL STRUCTURE

- The volumetric proportions of grains, bond material, and pores can be expressed as

$$P_g + P_b + P_p = 1 \qquad (1)$$

– P_g = proportion of abrasive grains in the total wheel volume

– P_b = proportion of bond material

– P_p = proportion of pores (air gaps)

(4) WHEEL STRUCTURE

- Wheel structure is measured on a scale that ranges between“ open” and “ dense. ”

- An open structure is one in which ***P_p*** is relatively ***large***, and ***P_g*** is relatively ***small***.

- That is, there are ***more pores*** and ***fewer grains*** per unit volume in a wheel of ***open structure***.

(4) WHEEL STRUCTURE

- Generally, open structures are recommended in situations in which clearance for chips must be provided.

- By contrast, a dense structure is one in which P_p is relatively ***small***, and P_g is ***larger.***

- Dense structures are used to obtain better surface finish and dimensional control.

(5) WHEEL GRADE

- Wheel grade indicates the grinding wheel's ***bond strength*** in ***retaining*** the ***abrasive*** grits during cutting.

- This is largely dependent on the amount of bonding material present in the wheel structure— P_b in Eq (1).

- Grade is measured on a scale that ranges between ***soft and hard***.

(5) WHEEL GRADE

- " ***Soft*** " wheels lose grains readily, whereas " ***hard*** " wheels retain their abrasive grains.

- ***Soft*** wheels are generally used for applications requiring ***low material removal*** rates and grinding of ***hard work*** materials.

- ***Hard*** wheels are typically used to achieve ***high stock removal*** rates and for grinding of relative ***soft work*** materials.

Grinding Wheel Specification

- The preceding parameters can be concisely designated in a standard grinding wheel marking system defined by the ***American National Standards Institute (ANSI).***

- This marking system uses numbers and letters to specify abrasive type, grit size, grade, structure, and bond material.

Marking System For **CONVENTIONAL GRINDING WHEELS**

Example: 51 – A – 36 – L – 5 – V – 23

Prefix	Abrasive type	Abrasive grain size	Grade	Structure	Bond type	Manufacturer's record
51	A	36	L	5	V	23

Prefix

Manufacturer's symbol
(indicating exact type of abrasive)
(use optional)

Abrasive type

- A Aluminium oxide
- C Silicon carbide

Abrasive grain size

Coarse	Medium	Fine	Very fine
8	30	70	220
10	36	80	240
12	46	90	280
14	54	100	320
16	60	120	400
20		150	500
24		180	600

Grade

Soft — **Medium** — **Hard**

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Grade scale

Structure

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

(Use optional)

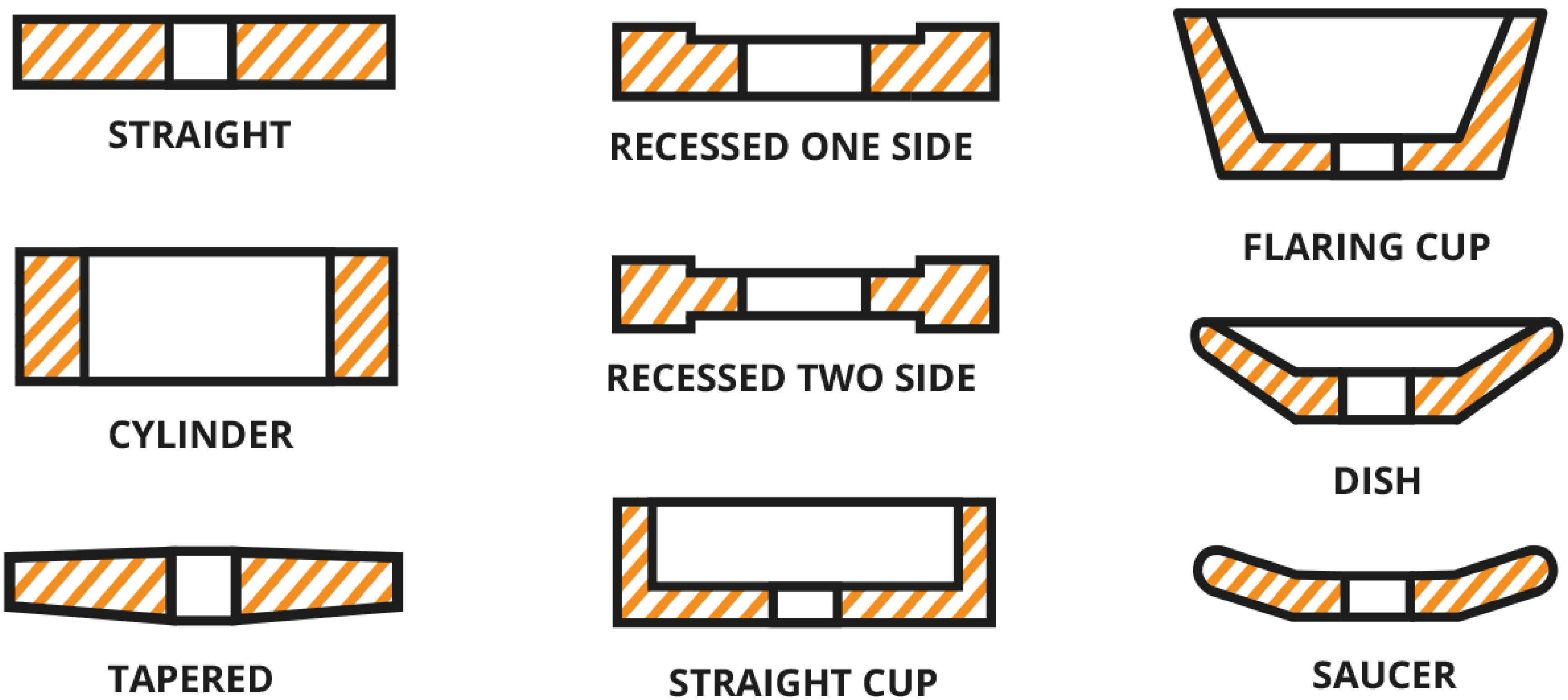
Bond type

B	Resinoid
BF	Resinoid reinforced
E	Shellac
O	Oxychloride
R	Rubber
RF	Rubber reinforced
S	Silicate
V	Vitrified

Manufacturer's record

Manufacturer's private marking
(to identify wheel)
(use optional)

GRINDING WHEEL SHAPES



WHEEL WEAR

- Grinding wheels wear, just as conventional cutting tools wear.
- Three mechanisms are recognized as the principal causes of wear in grinding wheels:

(1) grain fracture,

(2) attritious wear, and

(3) bond fracture.

(1) GRAIN FRACTURE

- ***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 cutting edges*** on the grinding wheel.
- The ***tendency*** of the grain to fracture is called ***friability.***
- ***High friability*** means that the ***grains fracture more readily*** because of the cutting forces on the grains .

(2) ATTRITIOUS WEAR

- ***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.
- It is caused by similar physical mechanisms including ***friction*** and ***diffusion***, as well as ***chemical reactions*** between the abrasive material and the work material in the presence of very high temperatures

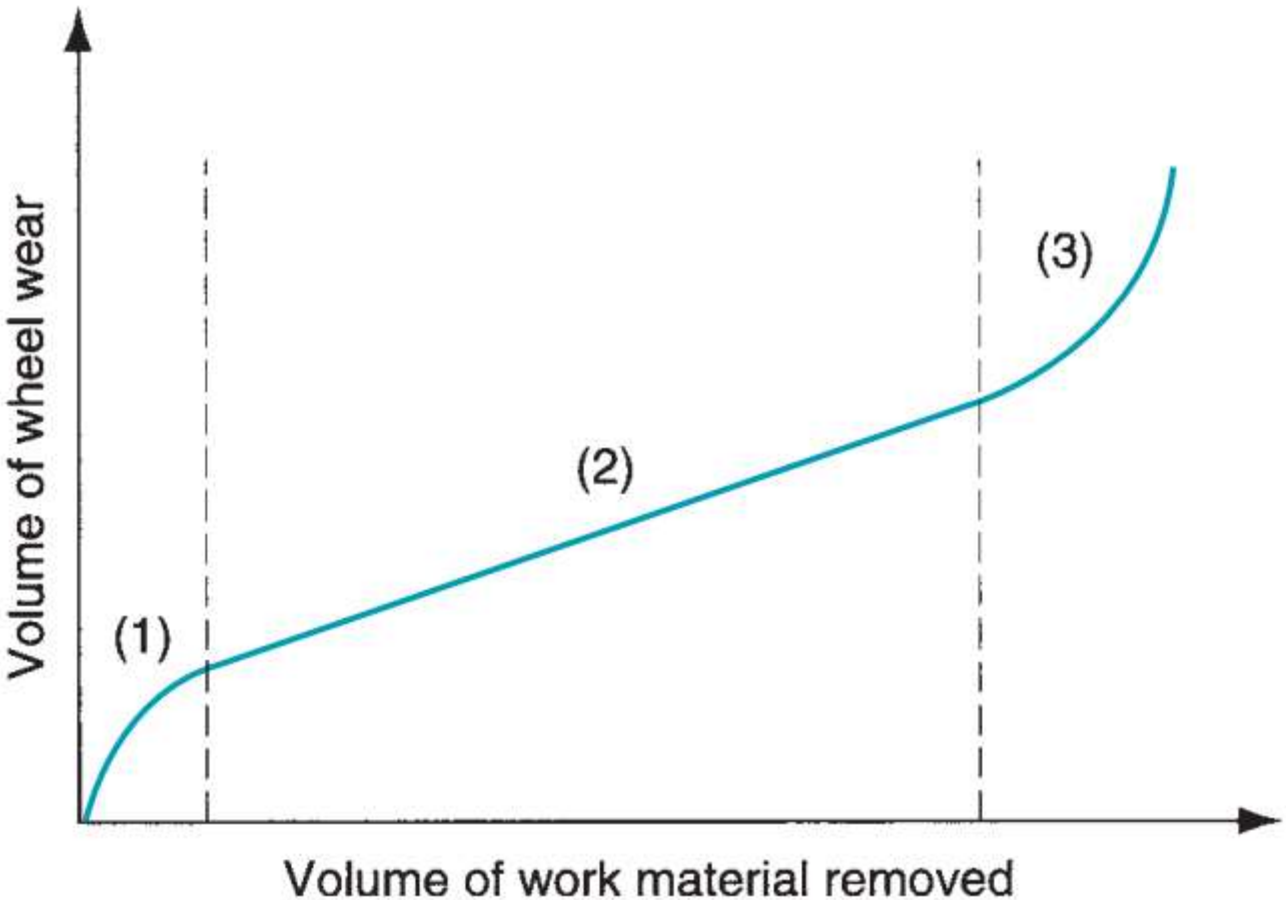
(3) BOND FRACTURE

- ***Bond fracture*** occurs when the individual ***grains are pulled out*** of the bonding material.
- The tendency toward this mechanism depends on wheel grade, among other factors.
- Bond fracture usually occurs because the grain has become dull because of 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.

WHEEL WEAR

- The three mechanisms combine to cause the grinding wheel to wear as depicted in Figure.
- Three wear regions can be identified.
- In the ***first region***, the grains are initially ***sharp***, and wear is accelerated because of grain ***fracture***.
- This corresponds to the“ break - in” period in conventional tool wear.

WHEEL WEAR



WHEEL WEAR

- In the ***second*** region, the ***wear rate*** is fairly ***constant***, resulting in a linear relationship between wheel wear and volume of metal removed.
- This region is characterized by ***attritious wear***, with some grain and bond fracture.
- In the ***third*** region of the wheel wear curve, the ***grains become dull*** , and the amount of plowing and rubbing increases relative to cutting.

WHEEL WEAR

- In addition, some of the ***chips*** become ***clogged*** in the ***pores*** of the wheel .
- This is called ***wheel loading*** ,and it ***impairs*** the ***cutting action*** and leads to higher heat and work surface temperatures.
- As a consequence, grinding ***efficiency decreases***, and the volume of wheel removed increases relative to the volume of metal removed.

GRINDING OPERATIONS

- Grinding is traditionally used to ***finish parts*** whose geometries have already been created by other operations.

- Grinding is also used in ***tool rooms to form the geometries on cutting tools.***

GRINDING OPERATIONS

(1) Surface Grinding,

(2) Cylindrical Grinding,

(3) Centerless Grinding.

(1) SURFACE GRINDING

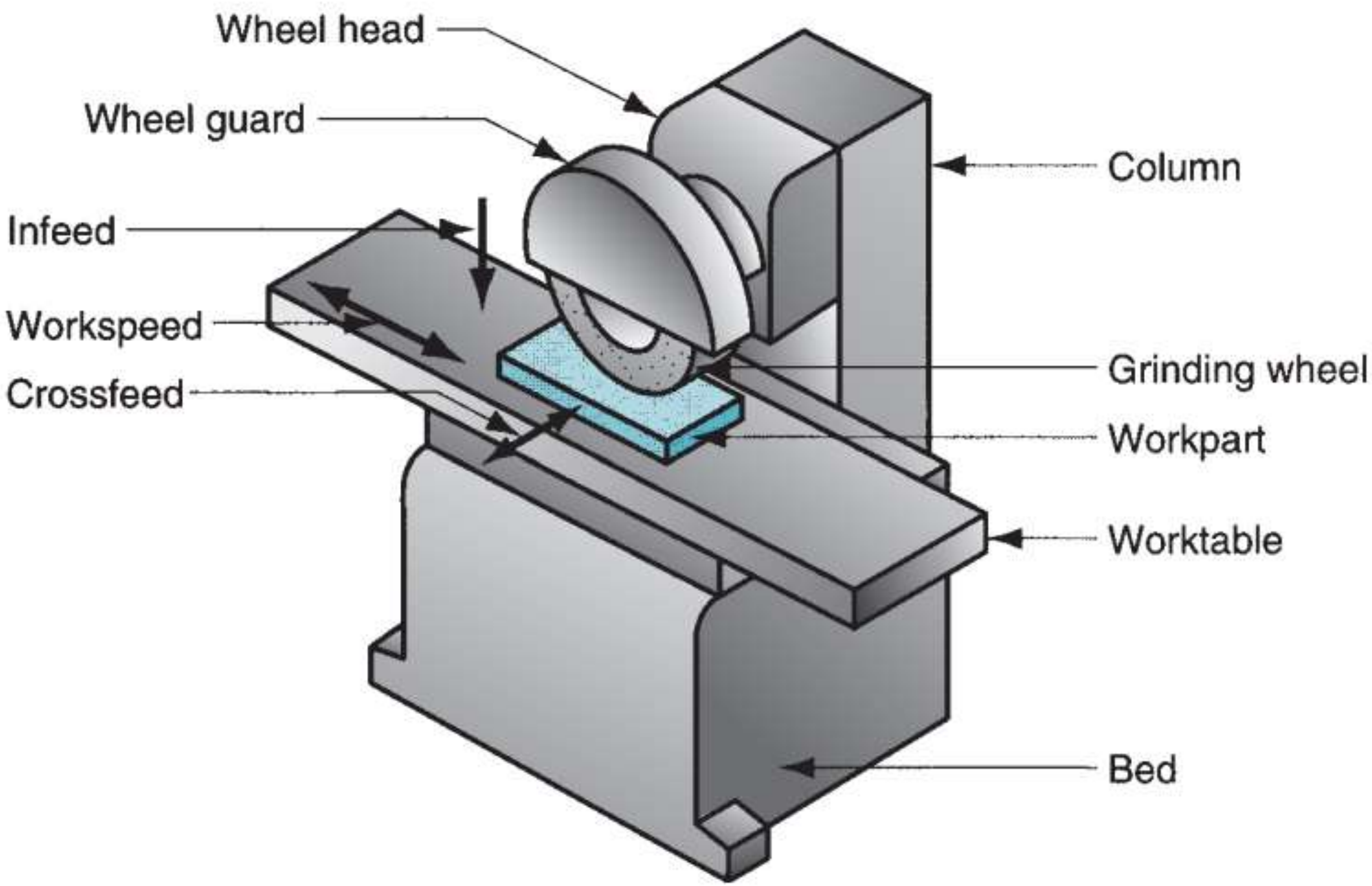
- ***Surface grinding*** is normally used to grind ***plain flat surfaces.***
- It is performed using either the ***periphery*** of the grinding wheel or the flat ***face*** of the wheel.
- Because the work is normally held in a horizontal orientation, ***peripheral*** grinding is performed by rotating the ***wheel*** about a ***horizontal axis***, and ***face*** grinding is performed by rotating the ***wheel*** about a ***vertical axis***.

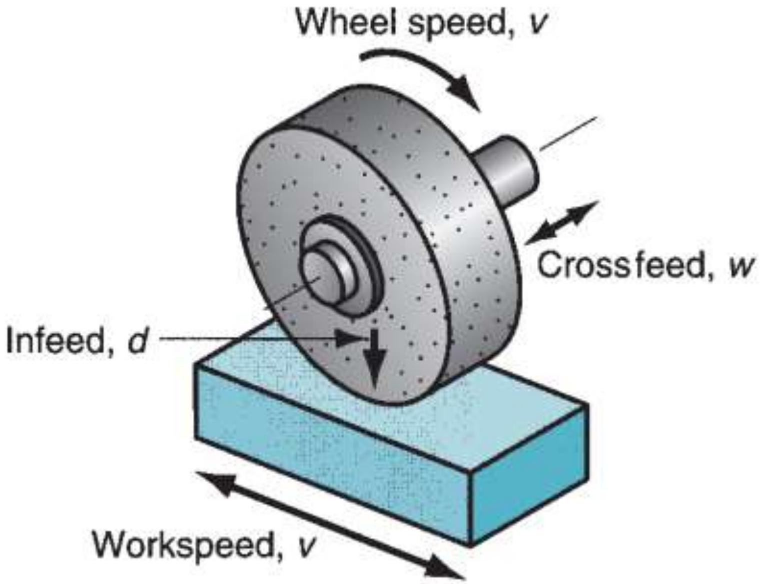
(1) SURFACE GRINDING

- In either case, the relative motion of the workpart is achieved by ***reciprocating*** the work past the wheel or by ***rotating*** it.

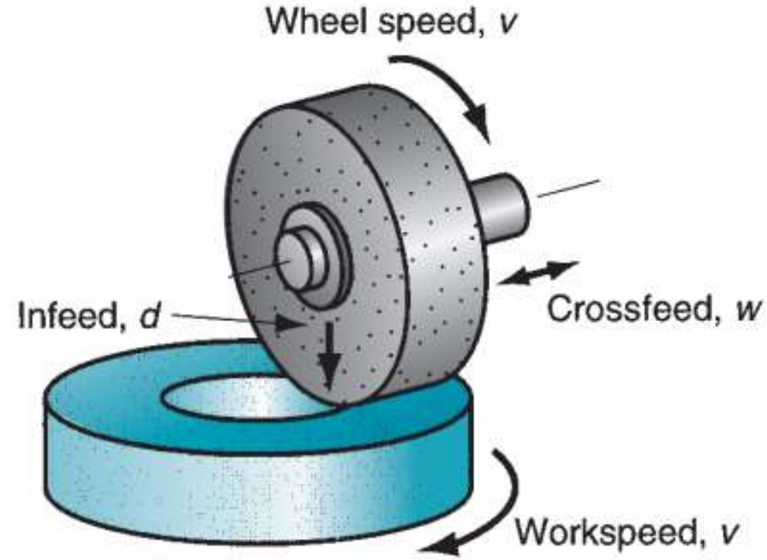
- These possible combinations of wheel orientations and workpart motions provide the four types of surface grinding machines illustrated in Figure.

(1) SURFACE GRINDING

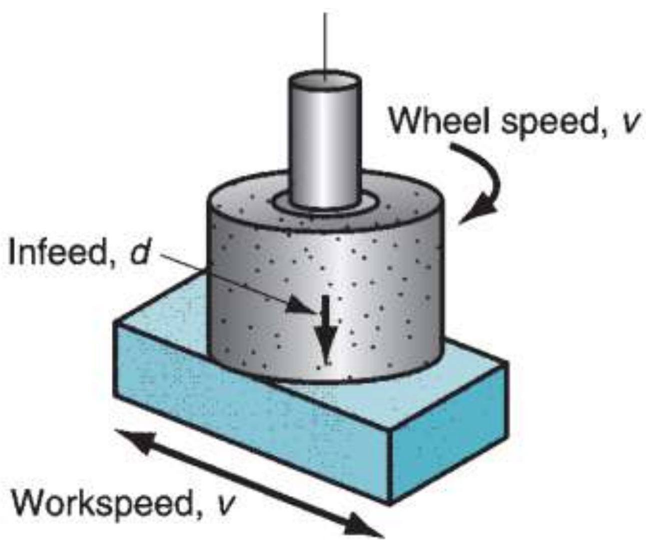




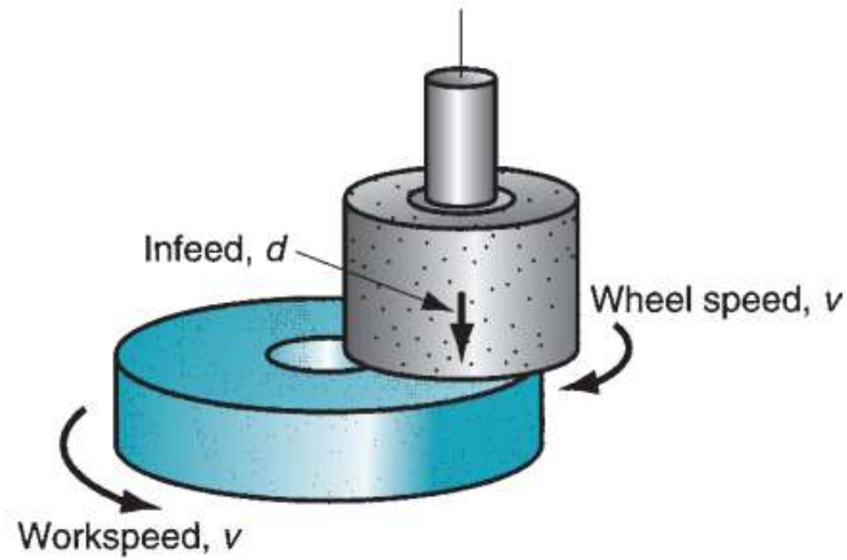
(**a**) Horizontal Spindle With Reciprocating Worktable



(**b**) Horizontal Spindle With Rotating Worktable



(**c**) Vertical Spindle With Reciprocating Worktable



(**d**) Vertical Spindle With Rotating Worktable

(1) SURFACE GRINDING

- Of the four types, the ***horizontal*** spindle machine with ***reciprocating worktable*** is the ***most common.***

- Grinding is accomplished by reciprocating the work longitudinally under the wheel at a ***very small depth*** (***infeed***) and by feeding the wheel transversely into the work a certain distance between strokes.

- In these operations, the width of the wheel is usually less than that of the workpiece.

(2) CYLINDRICAL GRINDING

- As its name suggests, cylindrical grinding is used for rotational parts. These grinding operations divide into two basic types:

(a) external cylindrical grinding and

(b) internal cylindrical grinding.

(2) EXTERNAL CYLINDRICAL GRINDING

- ***External cylindrical grinding*** (also called center-type grinding) is performed much ***like a turning*** operation.

- The cylindrical ***workpiece*** is rotated between centers, and the ***grinding wheel***, is engaged to perform the cut.

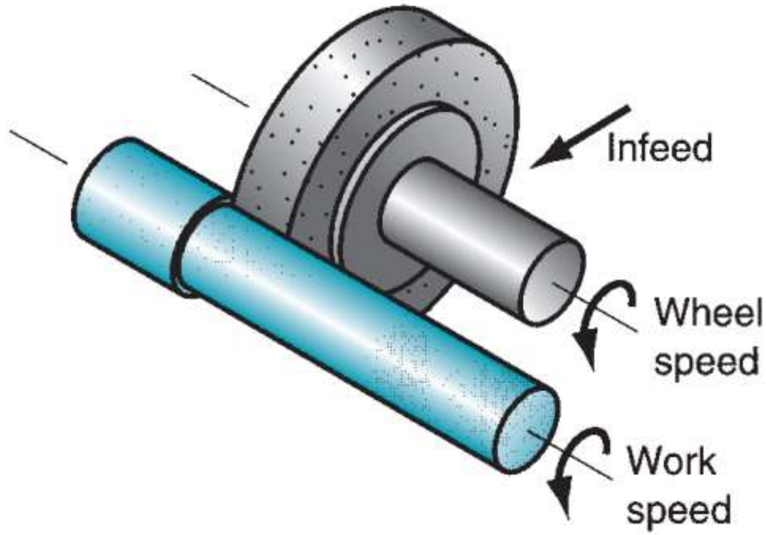
(2) EXTERNAL CYLINDRICAL GRINDING

- External cylindrical grinding is used to finish parts that have been machined to approximate size.

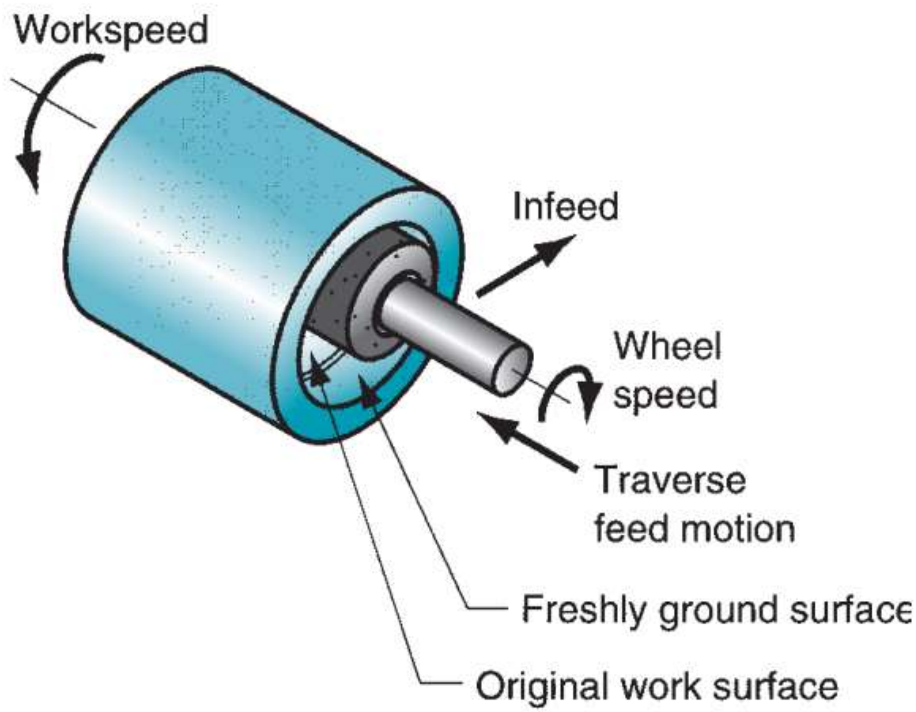
- The parts include ***axles, crank-shafts, spindles, bearings and bushings*** .

- The grinding operation produces the final size and required surface finish on these parts.

FIGURE



EXTERNAL CYLINDRICAL GRINDING



INTERNAL CYLINDRICAL GRINDING

(2) INTERNAL CYLINDRICAL GRINDING

- ***Internal cylindrical grinding*** operates somewhat ***like a boring*** operation.

- The work-piece is usually held in a chuck and rotated at a desirable speed.

- The ***wheel diameter*** in internal cylindrical grinding must be ***smaller*** than the ***original bore hole***.

(2) INTERNAL CYLINDRICAL GRINDING

- This often means that the wheel diameter is quite small, ***necessitating*** very ***high rotational speeds*** in order to achieve the desired surface speed.

- Internal cylindrical grinding is used to finish the inside surfaces of ***bearings and bushing surfaces.***

Problems Associated with Grinding

Problems:

- ***Glazing:***
- ***Wheel loading:***

Solutions:

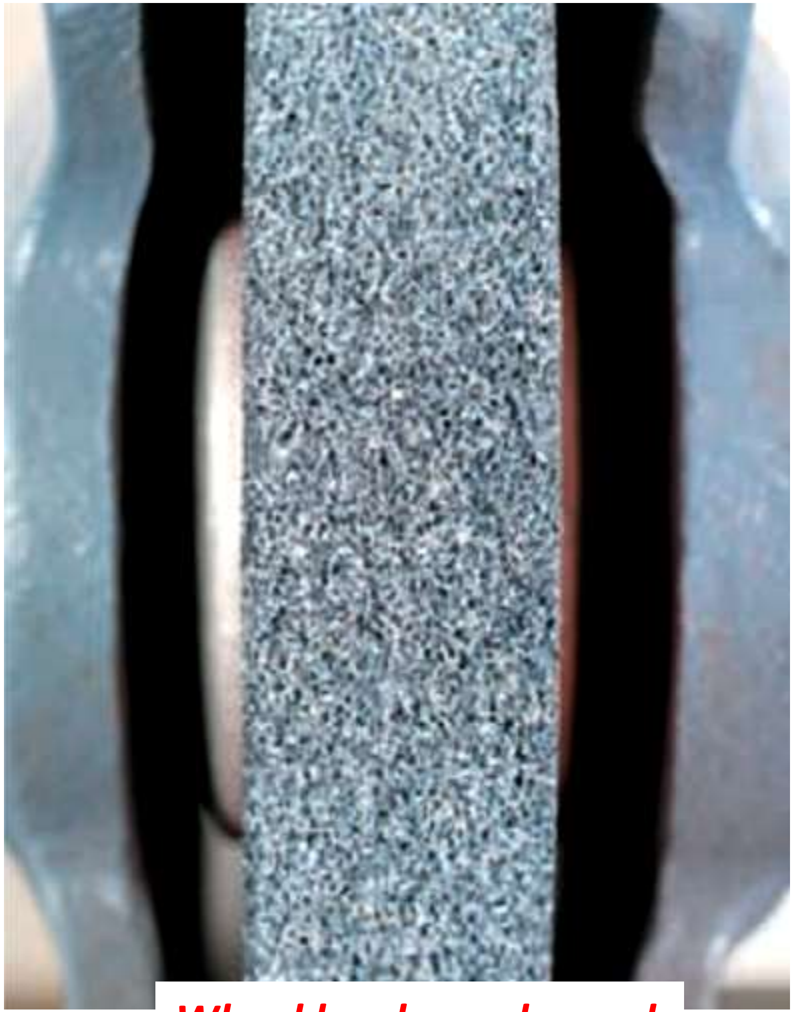
- ***Dressing***
- ***Truing***
- ***Balancing***

Glazing & Wheel loading

- ***Glazing:*** During grinding the high strength material, hard materials, abrasive edges of grinding wheel get dull because of their edges get rounded off. The surface of the wheel becomes smooth and shining and it ceases to cut effectively.
- ***Wheel loading:*** This is the process of the tiny chips being accumulated in the gap between the two successive grains called gullet. Again the tool ceases to cut efficiently.

Example of wheel Loading

Wheel has been loaded with bits of metal embedded in its grinding face



Wheel has been dressed to remove the loading.

Dressing and Truing

- To make a ‘glazed’ or ‘loaded’ abrasive wheel serviceable or to ‘true’ the wheel so that its circumference is concentric with the spindle axis, the ***wheel must be dressed***.

- There are ***various devices*** used to dress grinding wheels but they all have the same aims i.e.:

  1. ***To remove blunt grains*** from the matrix of the bond.

Dressing and Truing

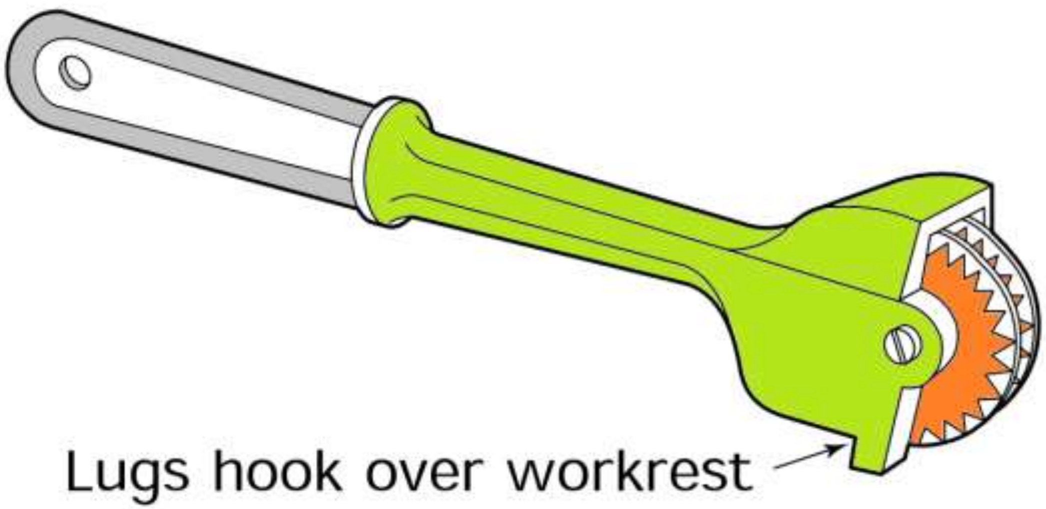
2. ***To fracture*** the blunt grains so that they exhibit fresh, sharp cutting edges.

3. ***To remove any foreign matter*** that may be embedded in the wheel.

4. ***To ensure the periphery*** of the wheel is concentric (running true) with the spindle axis.

Huntington type wheel dresser

- The ***star wheels dig into*** the wheel and break out the blunt grains and any foreign matter that may be clogging the wheel.



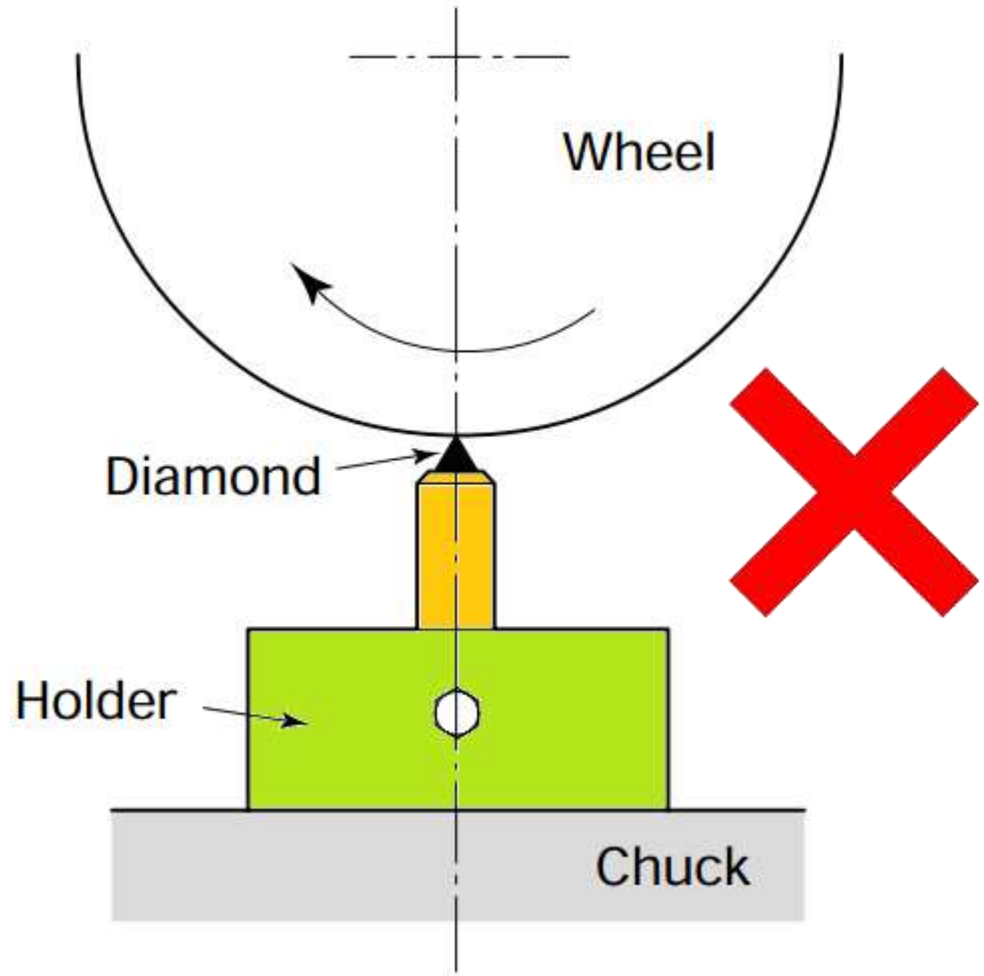
The diamond wheel dresser

- The diamond cuts the wheel to shape and is used for dressing and truing the wheels on precision grinding machines, such as surface and cylindrical grinding machines.

The diamond wheel dresser

- Figure shows the diamond being used ***incorrectly.***

- Used in this way, the diamond will develop a ‘flat’, and this will blunt the new grains as they are exposed



The diamond wheel dresser

- Figure shows the ***correct way*** to use the diamond.
- It should trail the direction of rotation of the wheel by an angle of 5° to 15°, but lead the centre of rotation slightly.
- This will maintain the shape of the diamond so that it will keep sharp and dress cleanly.