‘Abrasive’ Processes

- Involve the cutting action of thousands of sharp abrasive grains.
- The grains actually *cut* chips out of the work.
Abrasive Processes

- Many small cutting tools
  - hard, sharp and friable
- Bonded
  - wheels, discs, cups, sticks
- Loose
  - supporting medium
Common Abrasive Processes

- In order of decreasing removal rate and improving surface finish
  - Grinding
  - Honing
  - Lapping
  - Superfinishing
Self-Sharpening

- As grains/grits wear, they become blunt and forces increase. Ideally, grits then either fracture producing new sharp edges or are pulled out of the bond exposing new (sharp) grits.
Grinding

- Uses abrasives bonded in the form of wheels, cups, disks and mounted points

- Most common commercial abrasive process

- Two major types of grinding
  - offhand grinding
  - precision grinding
Offhand Grinding

- Manually applying wheel to workpiece or applying work offhand to grinding wheel
  - snagging castings
  - weld grinding
  - tool sharpening
  - miscellaneous rough grinding (incl. cutting off)
- Can have very high material removal rates
- Grinding to broad tolerances
Off hand/rough grinding
Precision Grinding

Several geometric arrangements are available.

Common operations are:
- cylindrical grinding
- surface grinding
- tool and cutter grinding
- complex arrangements of cylinders and surfaces
- centreless grinding
- specialised operations; e.g. crankshaft grinding
### Precision Grinding Operations

<table>
<thead>
<tr>
<th>Cylindrical grinding</th>
<th>Surface grinding</th>
<th>Centreless grinding</th>
</tr>
</thead>
<tbody>
<tr>
<td>External</td>
<td>Peripheral</td>
<td>External</td>
</tr>
<tr>
<td>Traverse</td>
<td>Face</td>
<td>Through-feed</td>
</tr>
<tr>
<td>Plunge</td>
<td>Stationary work</td>
<td>In-feed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>End-feed</td>
</tr>
</tbody>
</table>
Cylindrical Grinders

Center/Roll Type

Centerless Type

Cylindrical Grinding

- Axes of rotation of wheel and workpiece are parallel (usually)
- Periphery of wheel interferes with workpiece
- Traverse grinding (external)
  - workpiece moves ‘past’ wheel parallel to wheel’s axis of rotation
  - rotating workpiece axis produces conical sections
Cylindrical Grinding

- Plunge grinding (external)
  - wheel wider than workpiece, or plunge cut in sections
  - generally higher removal rates
  - can be used for putting a form on rolls

- Workpiece support (external)
  - betw’n dead centres with carrier & driving dog
    - steady needed for long &/or thin workpieces
  - chuck (usually independent type)
  - face plate
Cylindrical Grinding

A. Grinding wheel
B. Grinding face
C. Wheel spindle
D. Work piece
E. Work centers
F. Face plate
G. Dog

Movements
1. Wheel
2. Work (rotates)
3. Traverse
4. Infeed
Cylindrical Grinding
Cylindrical Grinding

**FIGURE 25.16** Examples of various cylindrical grinding operations. (a) Traverse grinding, (b) plunge grinding, and (c) profile grinding. Source: Okuma Machinery Works Ltd.

**FIGURE 25.17** Plunge grinding of a workpiece on a cylindrical grinder with the wheel dressed to a stepped shape. See also Fig. 25.12.
Cylindrical Grinding (Internal)

- Can be traverse or plunge
  - traverse most common
  - plunge can produce grooves
- Wheel must be smaller than initial opening of hole
  - high speed
  - spindle even smaller diameter
  - spindle must be long enough to reach back of hole
Cylindrical Grinding (Internal)

- For large work pieces, workpiece may be stationary and grinding wheel follows an orbital path
  - special grinders
- Most common is for workpiece to rotate
- Holding devices
  - chuck
  - on face plate
  - magnetic chuck (possible due to light loads)
Centreless Grinding (Internal)

- Work is supported by two support rolls and the control wheel

- Grinding occurs opposite the control wheel
  - provides maximum support
  - ensures uniform wall thickness
Internal Grinding

(a) Traverse grinding

Workpiece → Wheel

(b) Plunge grinding

Wheel → Work

(c) Profile grinding
Centreless Grinding (External)

- Does not rigidly support workpiece
- Quickly produces round parts
  - unless incorrectly set (lobes can result)
- Control wheel rotates and partly supports workpiece
- Workpiece rests on a blade above the line joining the centres of the control and grinding wheels
Centreless Grinding (External)

- **Through-feed**
  - tilt of control wheel imparts a feed force
  - suitable for long shafts
  - suitable for automation

- **In-feed**
  - for work with a portion larger than the ground diameter, or for simultaneous grinding of multiple diameters or any irregular profile

- **End-feed**
  - only for taper work
Centerless Grinding

A. Grinding wheel
B. Grinding face
C. Regulating wheel
D. Work piece
E. Work rest blade

Movements
1. Grinding wheel  2. Work
3. Regulating wheel  4. Infeed
5. Traverse

\( \theta = \text{Angle of tilt of regulating wheel} \)
Centerless Grinding
Surface Grinding

- Using wheel periphery
  - most common
  - usually wheel narrower than workpiece width
  - accommodates ‘odd’ shaped workpieces
  - suitable for form grinding
  - wheel/or workpiece is fed in two orthogonal directions (as well as incrementing depth)
Surface Grinding

- Using wheel face
  - higher removal rates
  - often wheel wider than workpiece
  - hence faster production
Surface Grinding

- Reciprocating workpiece
  - most common
  - suitable for rectangular workpieces

- Rotating workpiece
  - more efficient for circular workpieces

- Workpiece support
  - magnetic chucks
  - mechanically clamped
Surface Grinders

Type I

Reciprocating Table

Type II

Rotating Table

Grinding
Example of a Grinding Machine
Surface Grinding

Diagram showing parts of a surface grinding machine:
- Wheel guard
- Worktable
- Workpiece
- Saddle
- Feed
- Wheel head
- Column
- Bed
Grinding Wheel Parameters

- Grinding wheels consist of three components
  - grits/grains that do the cutting
    - hard, tough, friable when dull
  - bond posts that hold the grains in place
    - rigid or flexible
    - strong but will release dull grains
    - impervious to coolants
  - pores/voids that provide chip clearance space
Grinding wheel specification

- **11V9**
  - Wheel Type
    - Standard
    - Special

- **D**
  - Grit Size: 80 - 1800

- **180**
  - Grade
    - Letter from softer to harder

- **R**
  - Concentration
    - 50%
    - 75%
    - 100%
    - 125%

- **100**
  - Bond
    - B = Resin
    - M = Metal
    - V = Vitrified

- **B**
  - Abrasive Depth
    - 1/16""
Abrasives Grains

- Two groups
  - regular/common abrasives
    - $\text{Al}_2\text{O}_3$ and SiC
  - super abrasives
    - diamond and CBN
Aluminium Oxide

- Made from Bauxite, mixed with ground coke and iron filings and burnt for 15 - 25 hours at 2000°C

- Used for HIGH tensile strength materials such as carbon steel, alloy steel, high-speed steel, mild steel, stainless steel (magnetic), annealed malleable iron, wrought iron, hard bronzes, etc.
Aluminium Oxide

- Regular form is grey, used for heavy duty work, e.g. snagging, crankshafts, production cylindrical grinding except for most heat-sensitive steels

- Other special forms white or pink
  - e.g. 32A for tough vanadium alloy steels, 38A for hard, heat-sensitive steels
Silicon Carbide

- From chemical interaction of silica sand and coke at 2,600°C
- Used for LOW tensile strength such as gray iron, chilled iron, stainless steel (non-magnetic), brass, soft bronze, copper, aluminium, rubber, stone, marble, hard facing alloys and cemented carbides.
  - Chemically reacts with ferrous metals (except high C content)
Silicon Carbide

- Regular form is grey. Used for general grinding, heavy duty snagging, cylindrical, centreless and internal grinding
- Alternative form is green. Preferred for grinding cemented carbide tools
Super Abrasives

- Diamond
  - tungsten carbide, ceramics, glass, non-ferrous metals, glass reinforced plastics
- Cubic Boron Nitride
  - ferrous metals
    - (avoids affinity of diamond for the carbon in ferrous metals)
- Bonds
  - metal and resin
Grain Size

- Represented by openings per inch (25 mm) in screen to size.
- In practice wheels are composed of grains of several sizes
  - quoted value is a medium value of sizes present
- Affects production rate and surface finish, also friability
  - coarse for soft ductile materials
  - fine for hard brittle materials
Bonding Materials

- **Basic types**
  - vitrified
    - baked clays and feldspar
  - resinoid
    - phenollic type plastics
  - rubber
  - shellac
Vitrified Bonds

- 70 - 80% of all wheels
- porous and strong
  - high stock removal
- not affected by water, acid, oils or normal cutting temperature conditions
- rigid
  - high precision
Resinoid Bonds

- Variety of structures
  - hard, dense, coarse to soft, open, fine
- Cuts cool
- Can run at high speeds
- Rapid stock removal
- Used in foundries and for cut-off wheels
- Affected by alkalis, humidity
  - tend to deteriorate over time
Rubber Bonds

- Most centreless grinding control wheels
  - sometimes grinding wheels

- Strong and tough

- Thin cut-off wheels
  - reduced burr
Shellac Bonds

- Cool cutting of hardened steels
- High finishes on camshafts and mill rolls
- Fast stock removal
  - but not suited to heavy duty
Other Bonds

- **Silicate**
  - for edge tools where heat must be kept to a minimum. Very mild acting

- **Magnesite**
  - used for spring grinding
Hardness

- Describes ability of wheel to retain grains
- Depends on relative amounts of bond material to pores
  - \[ Q_a + (Q_b + d_1) + (Q_p - d_1) = 100 \] represents a harder wheel than \[ Q_a + Q_b + Q_p = 100 \]
- No internationally accepted testing method
- Variation found between manufacturers and batch-to-batch
Harder Wheel

- for softer work materials
- for rough grinding
- where coolant used
- for smaller workpieces
Structure

- Indicated by grain spacing
- Varied by relative proportions of abrasives and bonds
  - \((Q_a + d) + (Q_b - d) + Q_p = 100\) is a denser structure than \(Q_a + Q_b + Q_p = 100\)
- Most manufacturers provide controlled ‘optimal’ structures
Structure

- Manufacturers may offer special open (P) structures
  - for hard, dense fine-grained metals of low ductility
  - for soft ductile materials
  - for high stock removal
  - for hardened metals

- Dense structures needed for form work, including fillets and radii
Grinding Wheel Structure

Dense spacing  Medium spacing  Open spacing
Grinding Wheel Loading
Truing and Dressing

- Grinding wheels lose geometry during use and need truing
- Single point diamond dressing tool
- Infeed for dressing tool about .001 inch per pass
- 15° drag angle
- Cross feed
- Dressing stick pushed into at constant constant inf
- Grinding wheel
Wheel Selection

- 4 ‘constant’ factors
  - material to be ground (incl. hardness)
  - type (& condition) of operation
  - amount of stock to be removed and finish required
  - area of grinding contact
Wheel Selection

- 4 ‘variable’ factors
  - wheel (and work) speed
  - feed (pressure)
  - machine condition
  - operator skill
    - piece rates vs day rates
Other Performance Criteria

- **Volume of work material removed**
  
  
  \[
  \text{Grinding ratio} = \frac{\text{Volume of work material removed}}{\text{Volume of wheel worn}}
  \]

- **Grinding characteristic**
  
  \[
  \text{Grinding characteristic} = \frac{\text{Grinding ratio}}{\text{Net horsepower}}
  \]

- **Grinding rating**
  
  \[
  \text{Grinding rating} = \frac{\text{Grinding ratio}}{\text{Specific power x surface finish}}
  \]
Honing

Used mainly to improve the surface finish of holes

Bonded abrasives called stones are mounted on a rotating mandrel; also used on cylindrical or flat surfaces and to remove sharp edges on tools
Honing

FIGURE 25.27 Schematic illustration of a honing tool used to improve the surface finish of bored or ground holes.

Hole defects correctible by honing
Superfinishing/Microhoning

Uses very low pressure and short strokes

FIGURE 25.28  Schematic illustrations of the superfinishing process for a cylindrical part. (a) Cylindrical microhoning, (b) Centerless microhoning.
Lapping

Used to enhance surface finish and dimensional accuracy of flat or cylindrical surfaces; tolerances are on the order of .0004 mm; surface finish can be as smooth as .025-.1 μm; this improves the fit between surfaces

Abrasive particles are embedded in the lap or carried in a slurry

Pressures range from 7-140 kPa depending on workpiece hardness
FIGURE 25.29  (a) Schematic illustration of the lapping process. (b) Production lapping on flat surfaces. (c) Production lapping on cylindrical surfaces.
Example of a Lapping Machine
Lapping Finish

Grinding  Lapping
Types of Lapping

Single-sided lapping machine
Types of Lapping

Upper lap rotation

Lower lap rotation

Rolling cylindrical workpieces

Cylindrical Lapping

Double-sided lapping

Upper lap rotation

Lower lap rotation
Lapping Process
Examples of Lapped Parts

The workpieces made of aluminum oxide were rings having 0.5” ID, 0.8” OD and 0.2” thickness. Its high hardness promotes a series of applications in mechanical engineering, such as bearings and seals.

Initial Ra = 0.65 µm
Final Ra (after lapping) = 0.2 µm
Other Finishing Operations

Polishing

Produces a smooth, reflective surface finish; done with disks or belts with fine abrasive grains

Electropolishing

Produces mirror-like surfaces on metals; the electrolyte removes peaks and raised areas faster than lower areas; also used for deburring
Example of a Polishing Machine
Examples of Polished Parts

Polished disk drive heads compared to the size of a dime