Unit - 3

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Grinding : Grinding is a machining process used to remove small amounts of materials from a workpiece surface usually to achieve a specific finish, high accuracy or tight tolerance.

- It is commonly performed using a grinding wheel, an abrasive cutting tool made of grains bended together.

* Grinding process :

- The workpiece is fed into the rotating grinding wheel or vice versa.

- The abrasive grains on the wheel act as cutting edges removing materials by shearing microscope chips.

- Coolants are often used to reduce heat, improve the finish and prolong tool life.

* Applications of Grinding :

i) Surface finishing : Achieving a smooth, polished surface.

ii) Dimensional accuracy : Precise control of size and geometry.

iii) Hard Material machining : working with materials difficult to machine using conventional tools.

iv) Sharpening tools : Resparning cutting tools or removing worn layers.

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* Advantage :
(i) High precision and fine surface finishes.
(ii) Capable of machining hard materials.
(iii) Suitable for tight tolerances.

* Disadvantages :
i) Slower material removal rate compared to other machining methods.
ii) Generates heat that may affect workpiece properties if not properly controlled.

Abrasives : Abrasives are hard, tough materials used to wear down, smooth, polish or cut other materials through friction or grinding.

- They are commonly used in grinding, cutting, polishing and surface finishing applications, primarily in manufacturing and machining processes.

* Properties of Abrasives :

i) Hardness : Must be harder than the material being worked on.

ii) Toughness : Ability to withstand impact and resist breaking.

iii) Wear resistance : Maintain cutting edges over prolonged use.

iv) Shape retention : Resist deformation under high pressure applications.

* Types of abrasives :
Abrasives are classified into two main categories

i) Natural Abrasives :
Example : Diamond, emery, garnet, quartz, pumice

uses : Historically significant but less common in modern industries, except for natural diamonds in specialized applications.

(ii) Artificial (synthetic) abrasives :
Example : Aluminium oxide, Silicon Carbide, synthetic diamond, Cubic boron nitride (CBN)

Advantages : Engineered for specific properties, consistent quality and enhanced durability.

* forms of abrasives :

i) loose grains : found in polishing powders and blasting media.
ii) Bonded abrasives : Grains embedded in a matrix (e.g - grinding wheels, honing stones)

iii) Coated abrasives : Grains bonded to a backing material (e.g - Sandpaper, abrasive belts.)

iv) Superabrasives : High performance abrasives like diamond and CBN, used in demanding applications.

* Applications :

i) Grinding : Material removal to achieve precision and surface finish.

(ii) Cutting :- Abrasive saws or water-jet cutting with abrasive media.

iii) Polishing – Creating a smooth, reflective surface (e.g. in jewelry or automotive industries)

iv) Sharpening tools : Maintaing the edge on cutting tools like blades and drill bits.

v) Abrasive blasting : Surface cleaning and preparation (eg – Sand blasting)

Applications of Natural abrasives :

Natural abrasives are naturally occuring materials that posses sufficient hardness and toughness to be used for grinding, cutting, polishing or finishing surfaces.

i) Sand stone :

- used as grindstones for sharpening tools and knives
- Employed in stone carving and sculpture for shaping and smoothing surfaces.
- used as millstones in traditional milling process
- In construction, as a natural abrasive for surface finishing.

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(ii) Quartz :

- used in Sandblasting to clean Surfaces and prepare them for painting or coating.
- Incorporated in abrasive papers (Sandpaper) for wood and metal finishing.
- utilized in glass Cutting and polishing.
- forms a Component in grinding wheels for light duty applications.

(iii) Corundum

- widely used in grinding wheels and Cutting tools for machining metals.
- Employed in the polishing of precious Stones and jewelry.
- found in Sandpaper and emery boards for surface Smoothing.
- Applied in the prepartion of refractory materials for high temperature industries.

(iv) Emery :

- used in emery cloth and paper for Smoothing metal, wood and plastic Surfaces.
- Incomporated in grinding and polishing applications for metalworking.
- Employed in shoe repairs shops for polishing and shaping Soles.
- used in sharpening tools and blades.

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Applications of Manufactured abrasives :

Manufactured abrasives are Synthetic materials produced through Controlled processes to achieve consistent hardness, toughness and grain Size.

i) Silicon Carbide (SiC)

properties : Extremly hard, brittle, and heat ~~trea~~ restant.

Applications –

- Grindings : used in grinding wheels for machining metals, Ceramics and cast iron.
- Cutting :- Incorporated in Cutting tools for hard materials like glass and stone.
- Coated abrasives : used in Sandpapers for wood, plastic and metal finishing.
- Refractories : used in furnance linings and high-temperature applications.
- Polishing : Applied in polishing marble and granite.

ii) Aluminium oxide (Al_2O_3) :

Properties : High hardness, toughness and thermal Stability.

Application :

- Grinding and sharpening : used in grinding wheels for steel, alloys and non-ferrous metal.

- Coated abrasives : found in Sand paper for metal finishing & and wood sanding.
- Cutting tools : used in abrasive discs for cutting hard and soft metals.
- polishing : Employed in fine polishing of surface in the automotive and aerospace industries.
- Blasting : used in abrasive blasting for cleaning and surface preparation.

(iii) Cubic Boron Nitride (CBN) :

Properties : Second only to diamond in hardness, excellent thermal and chemical stability.

Applications :

- precision grinding : Ideal for machining hardned steels and superalloys.
- Cutting tools : used in tools for high speed and precision cutting.
- Polishing : Employed in achieving ultra smooth finishes on hard materials.
- Aerospace and automotive : used in machining turbine components and engine parts.
- Tool Sharpening : Perferred for sharpening cutting tools due to its long life and efficiency.

* Advantages of manufactured abrasives:
- Consistant quality and predictable performance
- customizable properties to suit specific applications.
- higher durability and efficiency compared to natural abrasives.

- Grit, Grade, Structure and bond type are key factors in the design and performance of abrasive tool like grinding wheels. They determine the tools cutting ability, surface finish and durability.

Grit (Grain Size): It refers to the size of the abrasives particles (grains) used in the tool.

* Classification:

i) Coarse grit (8-24): large particles for heavy material removal and rough surfaces.

ii) Medium grit (30-60): Moderate particles for general purpose grinding.

iii) fine grit (70-220): Small particles for precision grinding and smooth surfaces.

iv) Super fine grit (240 and above): Extremly fine particles for polishing and finishing.

* Application :
- Coarse grit is used for heavy stock removal
- fine grit is ideal for precision grinding such tool sharpening or surface grinding.

Grade : It refers to the hardness or strength of the bond that holds the abrasives grains together

Classification :

i) Soft grade :- Grains are released quickly, suitable for grinding hard materials where fast cutting is needed.

ii) Hard grade : Grains are retained longer, ideal for grinding soft materials or high pressure operations

Applications :
- Soft grades for hard metal like carbide or glass
- Hard grades for soft metals like aluminium or mild steel.

Structure : Structure refers to the spacing betn abrasives grains in the tool.

Classification :

i) Dense Structure (closed) : Grains are closely packed, providing a fine finish.

ii) Open Structure : Grains are spaced farther apart allowing for better chip clearance and reduced heat buildup.

Applications :

- Dense structure for precision grinding and fine finishes.
- open structure for grinding soft or gummy materials that may clog the wheel.

Bond type : It refers to the material used to hold the abrasive grains together.

Types :

i) Vitrified bond :

- Made from ceramic or glass-like materials
- High strength, rigidity and thermal resistance.
- used in precision grinding.

ii) Resinoid bond :

- Made from synthetic resin.
- flexible and shock resistant
- used for high speed operations and heavy duty applications.

iii) Metal bond :

- Made from metals like bronze or steel
- Extremely durable and wear resistant.
- used in diamond or CBN grinding wheels.

iv) Rubber bond :

- flexible and smooth cutting.
- used for fine polishing and finishing.

(v) Electroplated bond :

- Abrasive grains are electroplated onto a metal
- used in applications requiring high-precision or Specific shapes.

Iso designation of grinding wheels :

The ISO designation of grinding wheels provides a Standarized method to Specify the Composition and characteristics of grinding wheels, ensuring uniformity and Compatibility across industries world wide.

The designation typically follows the format defin in ISO 525, ISO 6104 and related Standards. It includes the following key elements :

* Typical ISO designation format :

[Prefix] - Abrasive type - Grit Size - Grade - Structure - Bond type.

i) Abrasive type (letter) : It indicates the abrasive material used in the grinding wheel.

A : Aluminium oxide

C : Silicon Carbide

D : Diamond

B : Cubic boron nitride (CBN)

(ii) Grit Size (Number) : It refers to the Size of the abrasive grains (Measured in mesh Size) :

- Coarse : 8-24
- Medium : 30-60
- fine : 70-180
- Very fine : 220 and above.

(iii) Grade (letter) : It denotes the hardness of the wheel (resistance to grain shedding) :
- Soft : A – H
- Medium : I – P
- Hard : Q – Z

(iv) Structure (Number) : It indicates the spacing betⁿ abrasive grains :
- Dense : 1–5 (fine finishes)
- open : 6–15 (high stock removal)

(v) Bond type : It specifies the bonding material :
V : Vitrified
B : Resinoid (Bakelite)
E : Shellac
M : Metal
R : Rubber

(vi) Additional information (optional) : It includes wheel dimensions, operating speed and manufacturer's details.

Examples of an ISO grinding wheel designation :-
A 46 K 5 V
A : Aluminium oxide abrasive
46 : Medium grit size
K : Medium hardness
5 : Medium structure
V : Vitrified bond.

Wheel dimensions (Standardized format) :
Typically written as : Diameter X Thickness X Bore s
Example : 400 x 50 x 127 mm

Supplementry making : Grinding wheels often hav
markings for safety and operational Conditions:

- Max Speed : Maximum allowable rotational Speed (eg-

- Color Code : Indicates the material is Suitable for
  (eg- green for carbide).

Tool geometry

Tool geometry refers to the shape, angles and dimensions of a cutting tool, which directly affects its cutting performance and the quality of the workpiece.

* Elements of tool geometry :

i) Shank : The part of the tool that is clamped in the machine tool or tool holder.
- provides support and stability of ~~the workpiece~~ during the machining process.

(ii) Cutting edge : The edge of the tool that comes in contact with the workpiece and performs the cutting action.

(iii) Rake face : The Surface of the tool over which the chips flow during machining.
- Its angle is referred to as the rake angle.

(iv) flank face : The Surface of the tool adjacent to the Cutting edge that faces the workpiece.
- provides clearance to avoid rubbing against the workpiece.

(v) Tool Tip / Nose : The point where the rake and flank faces meet.

- often rounded or chamfered to improve tool strength and surface finish.

* Angles in tool geometry :-

i) Rake angle (α) : The angle betn the rake face and a perpendicular line to the Cutting Surface.

Types -
- Positive rake : reduces Cutting forces and improve chip flow (used for soft materials)
- Negative rake : strengthness the cutting edge (used for hard materials)

Affects cutting efficiency, clip flow and heat generation.

(ii) Relief / clearance - angle (γ) : The angle betn the ~~formed~~ flank face and the workpiece surface.
- Prevents the tool from rubbing against the workpiece, reducing heat and wear.

(iii) Cutting edge angle (λ): The angle formed by the Cutting edge and the tool's axis.
- Affects chips formation and Surface finish

(iv) Nose radius (r) : The radius of the tool's tip or nose.
- A larger nose radius improves Surface finish and tool strength but increases Cutting forces.

(v) Approach angle / lead angle (ψ) : The angle betⁿ the Cutting edge and the direction of tool feed.
- Influences chip width and distribution of Cutting forces.

Tool Materials and designation :

Tool materials and their designation are fundamental in machining because they determine the tools ability to withstand wear, heat and Cutting forces while maintaining Performance.

* Tool materials :

Tool materials must Possess properties like hardness, toughness, thermal resistance and wear resistance. Common tool materials include :

i) Carbon tool Steels :

- Composition : Carbon (0.6 – 1.5%) with small amounts of manganese and Silicon.

- properties : i) Good hardness
  ii) low cost
  iii) poor heat resistance (~ 250°c)

- Applications : light duty tools like hand tools and wood cutting tools.

ii) High Speed Steels :
- Composition : Alloyed with tungsten, molybdenum, chromium and vanadium.

- Properties : i) Retain hardness upto 6000°c
  ii) Tough and wear-resistant.

- Applications : Drills, tapes, milling cutters and lathe tools.

(iii) Cemented Carbides :
- Composition : Tungesten Carbide (WC) bonded with Cobalt.
- properties :
  i) High hardness and wear resistance.
  ii) operates at high cutting Speeds.
  iii) Heat resistance (~1000°c)
- Applications : Turning, milling and heavy duty machining.

iv) Ceramics :
- Composition : Aluminium oxide (Al_2O_3) or Silicon nitride (Si_3N_4)
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- Properties : (i) High hardness and temperature resistance (~1200°c)
ii) Brittle and not Suitable for interrupted Cuts.

- Applications : High speed finishing operations.

(v) Carmets :
- Composition : Combination of Ceramic and metals

- Properties : (i) High wear resistance.
(ii) Moderate toughness.

- Applications : Precision machining.

(vi) Diamond and Cubic boron nitride (CBN):
- Diamond : Hardest known material, excellent for non-ferrous materials.

- CBN : Second hardest, used for ferrous materi

- Applications : Super finishing and high precision machining.

(vii) Coated tools :
- Coating materials : Titanium nitride (Tin, alumini oxide (Al_2O_3) or Titanium Carbide (Tin).)

- Properties : Improves wear resistance, heat resist and lubricity.

- Applications : Versatile across various cutting operat

Tool Designation :

The designation of cutting tools varies based on the material type and standard systems like IOS (International organization for Standardization). These system define tool geometry and composition :

i) ISO Tool designation for inserts :

- Standard format : PCLNR 2525 M12

Each part describes a specific feature :

P : Insert Shape (e.g: P for Square, D for diamond)
C : Clearance angle.
L : Hand of tool (left, right, neutral)
N : Insert holder style
R : Cutting edge style
M12 : Insert size and clamping method.
2525 : Tool shank dimensions.

(ii) Designation by Material groups :

P (Blue) : for steels
M (Yellow) : for stainless steels
K (Red) : for cast irons
N (Green) : for non-ferrous materials
S (orange) : for Superalloys and Titanium
N (Grey) : for hardned steels.

Tool life and wear :

Tool life refers to the duration a cutting tool can perform efficiently before it becomes unsuitable for machining due to excessive wear or damage. Tool wear is the gradual loss of materials from the cutting tool due to mechanical, thermal and chemical interactions during machining.

* Tool life : Tool life is the time or amount of material machined before the tool requires replacement or resharpening.

Factors influencing tool life :

i) Tool materials : Harder materials like Ceramics and Carbides generally last longer than softer materials like high speed steel.

ii) workpiece materials : Hard or abrasive materials cause faster tool wear.

iii) Cutting Speed : Higher Speeds generate more heat, reducing tool life.

iv) Feed rate and depth of cut : Higher feed rates and depth increase tool wear.

v) Cutting fluids : Coolants and lubricants help reduce heat and friction, extending tool life.

(vi) Tool geometry : Proper rake angle, clearance angle and nose radius optimize performance and wear resistance.

(vii) Machining environment : Conditions like vibration interrupted cuts and temperature fluctuations can shorten tool life.

* Tool wear : Tool wear is the gradual deterioration of the tools cutting edge or surface during operation.
It affects cutting performance and surface finish.

* Types of tool wear :

i) Flank wear : occurs on the tool's flank (relief) face.
- Caused by friction betn the tool and the machined surface.
- Affects surface finish and dimensional accuracy.

ii) Crater wear :
- occurs on the tool's rake face due to friction and chemical interactions with chips.
- leads to loss of cutting edge strength.

(iii) Notch wear :
- forms near the cutting edge at the workpiece-tool interface.
- Common when cutting abrasive or hard material.

(iv) Built up edge (BUE) :

- A layer of workpiece material adheres to the tool edge.
- Affects surface finish and causes unpredicatable cut

(v) Chipping :

- Small fragments break off the cutting edge.
- occurs due to mechanical overload or vibration

(vi) Thermal wear :

- High temperature cause chemical reactions, diffusion or melting at the cutting edge.

* Taylor's tool life equation :

$$\boxed{VT^n = C}$$

where, V = Cutting speed (m/min)

T = Tool life

C = Constant for given w/P

n = tool life exponent (material dependent)

Cutting Speed (v) : Cutting speed refers to the speed at which the cutting edge of a tool moves relative to the surface of the workpiece.

- It is measured in meters per minute (m/min) or feet per minute (ft/min).

$$V = \frac{\pi D N}{1000}$$

where, V = Cutting speed (m/min)

D = Diameter of the workpiece (mm)

N = Spindle Speed (revolutions per minute, RPM)

- Cutting Speed directly affects heat generation, tool wear and machining efficiency.

- Higher Cutting Speeds generally result in faster machining but can increase tool wear.

Depth of Cut (d) : Depth of Cut is the thickness of the material layer removed during one pass of the Cutting tool.

It is the perpendicular distance betⁿ the machined Surface and the unmachined Surface measured in millimeters (mm).

$$d = \frac{D_1 - D_2}{2}$$

where,

D_1 = Initial diameter of the workpiece.

D_2 = final diameter after machining.

- Increasing the depth of Cut removes more material per pass but increases cutting forces and tool wear.
- It is usually set based on the material, tool strength and machine capacity.

feed (f) : feed refers to the distance the Cutting tool moves relative to the workpiece during one revolution of the workpiece (in turning) or one stroke (in other machining processes).

It is typically measured in millimeters per revolution (mm/rev) or millimeters per minute (mm/min)

* Types of feed :

(i) feed per revolution : (Turning) Distance per workpiece revolution.

(ii) feed per tooth (Millings) : Distance each tooth of a Cutter travels in one revolution.

(iii) Feed rate : overall Speed of tool movement combining Spindle Speed and feed per revolution.

- Proper feed ensures efficient material removal and good Surface finish.
- High feed rates increases productivity but Can Cause Poor Surface finish and tool damage.

* Material removal Rate (MRR) :

$$MRR = V \times f \times d$$