Metal Machining

Bachelor of Industrial Technology Management with Honours

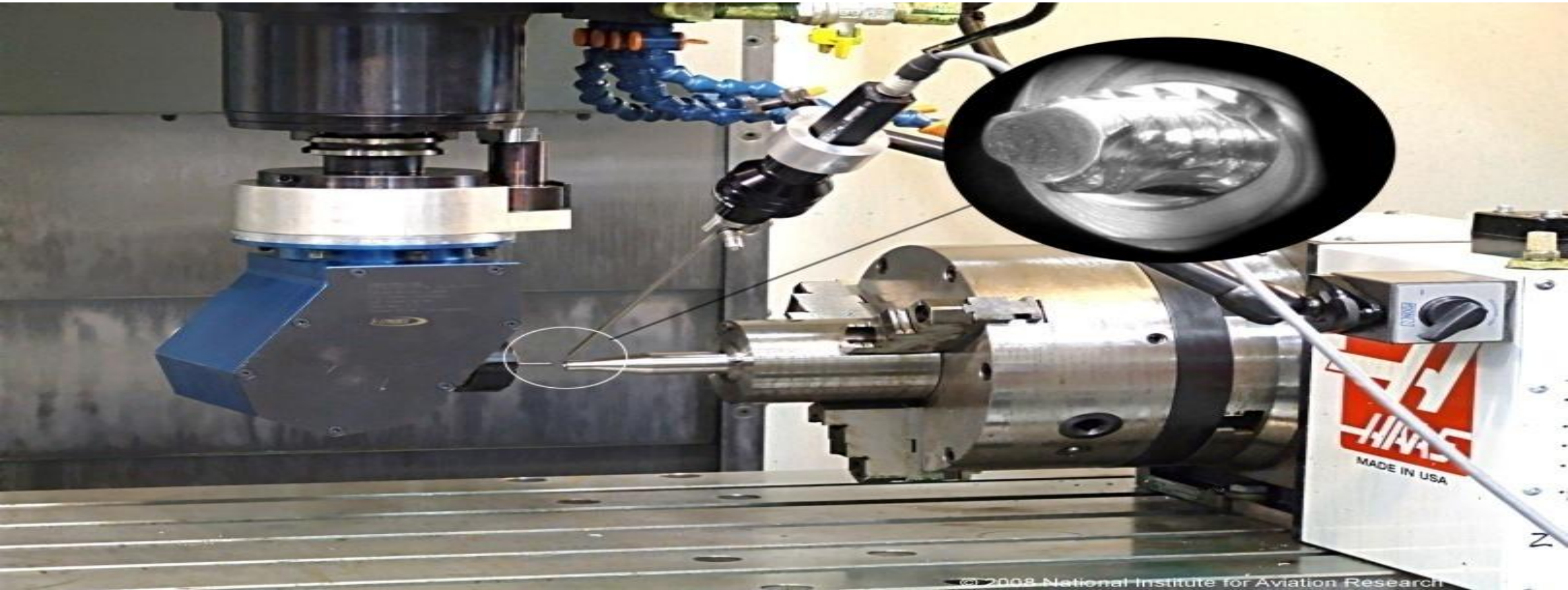
Semester I Session 2013/2014

TOPIC OUTLINE

- Introduction
- Mechanics of Cutting
- Cutting Conditions
- Chip Formation
- Types of Cutting
- Cutting Tool Materials
- Tool Wear and Tool Life
- Cutting Fluid
- Surface Finish

LESSON OUTCOMES

1. Able to explain the fundamentals of metal cutting
2. Able to select appropriate machining operations for producing products with different specifications



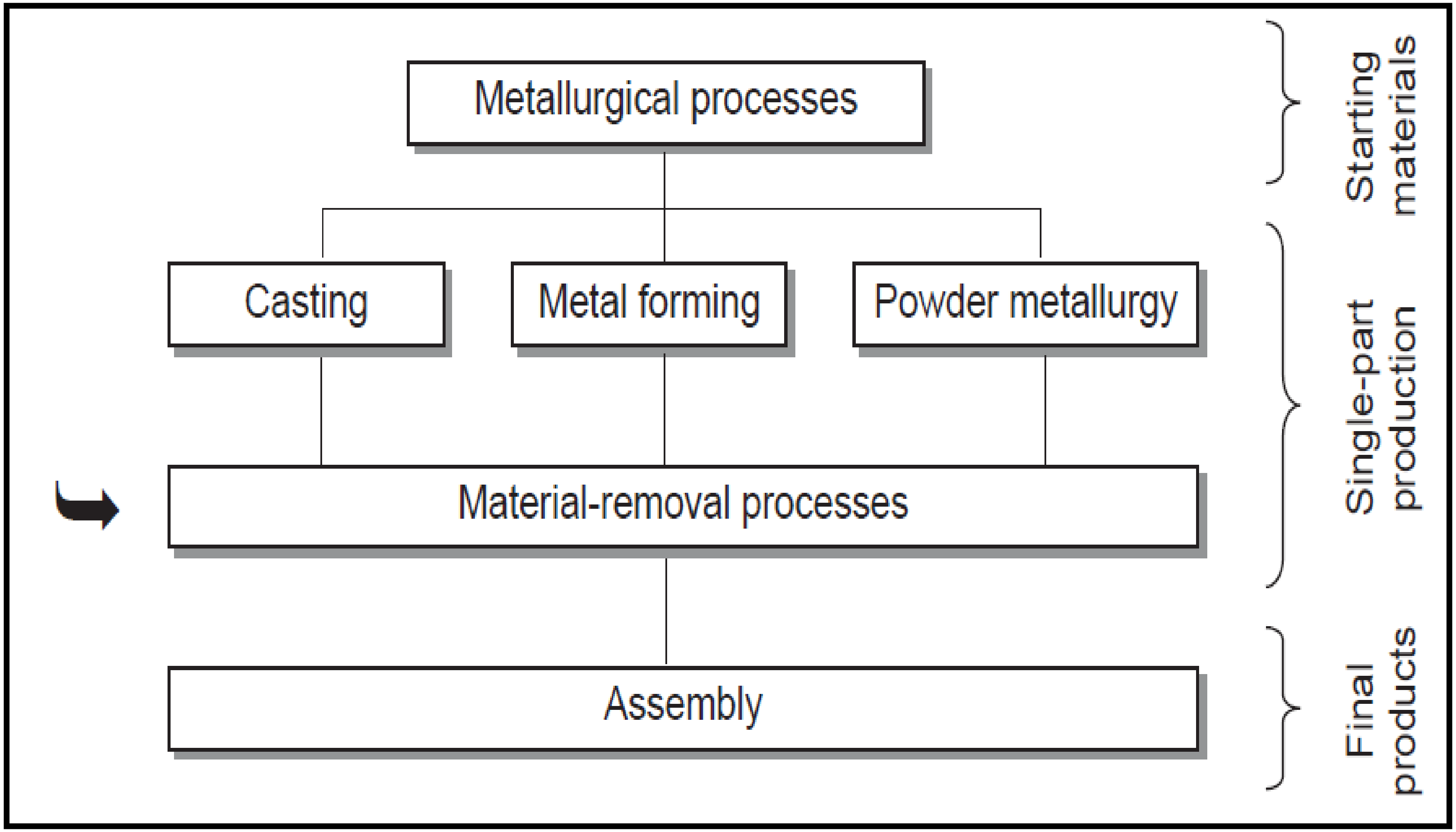
INTRODUCTION

Classification of Manufacturing Process

1. Primary Processes
   - Eg.: Casting, Forging, Molding, etc.
2. Secondary Processes
   - Eg.: Machining
3. Tertiary - Assembly
   - Eg.: Fabricating like Welding, Brazing, Riveting, etc.
4. Finishing and Surface Treatment – Aesthetic Look
   - Eg.: Painting, Electroplating, etc.

INTRODUCTION

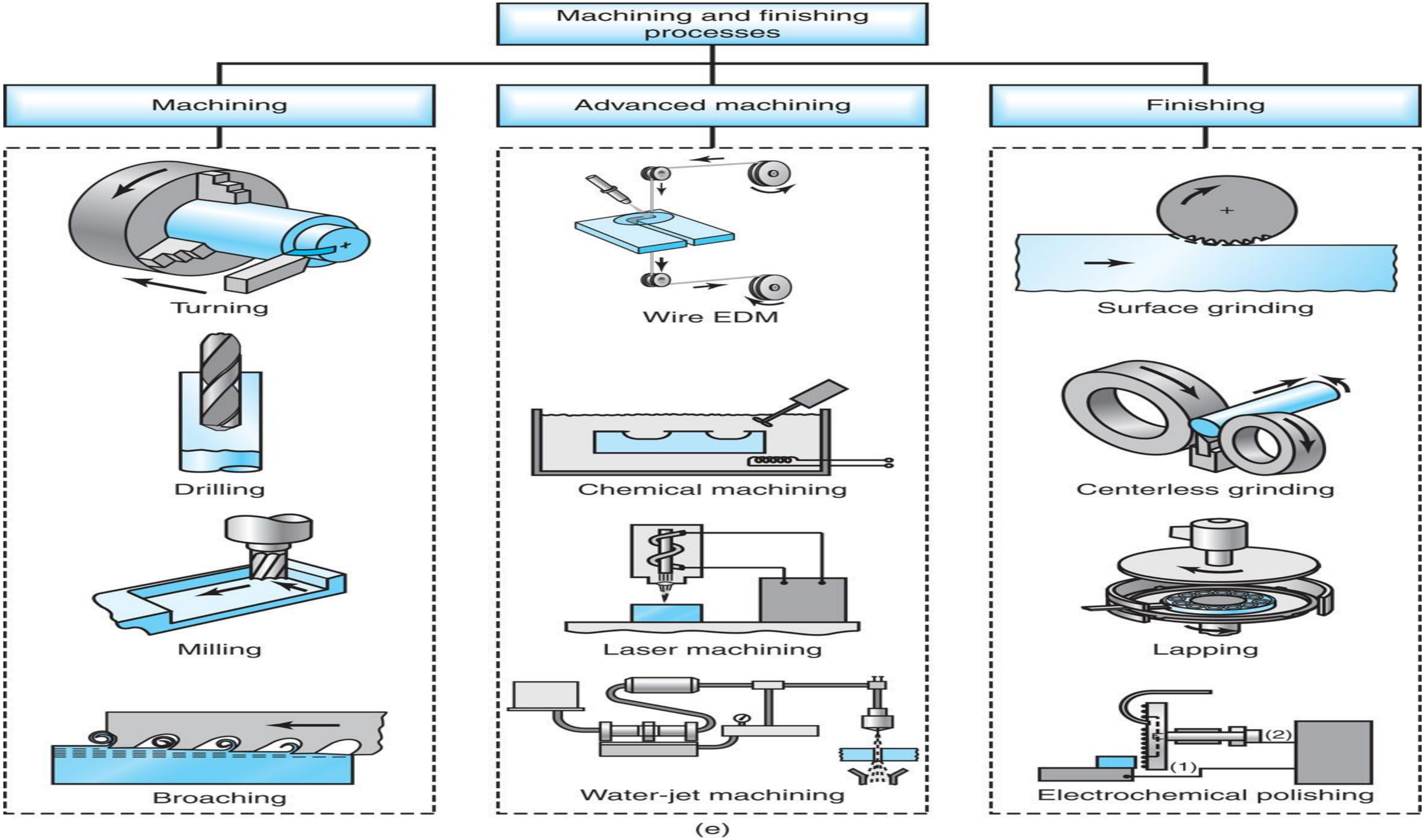
The place of machining operations within the entire production cycle



MACHINING PROCESS

- Machining is a manufacturing process in which sharp cutting tool is used to cut away material to leave the desired part shape
- The predominant cutting action in machining involves shear deformation of the work material to form a chip : process of removing unwanted material from a work piece in the form of chips
- Performed after other processes which provides final shape, more precise dimensions and smooth surface finishes.
- Material removal process – excess material is removed from a starting work part so that what remains is the desired final geometry

INTRODUCTION

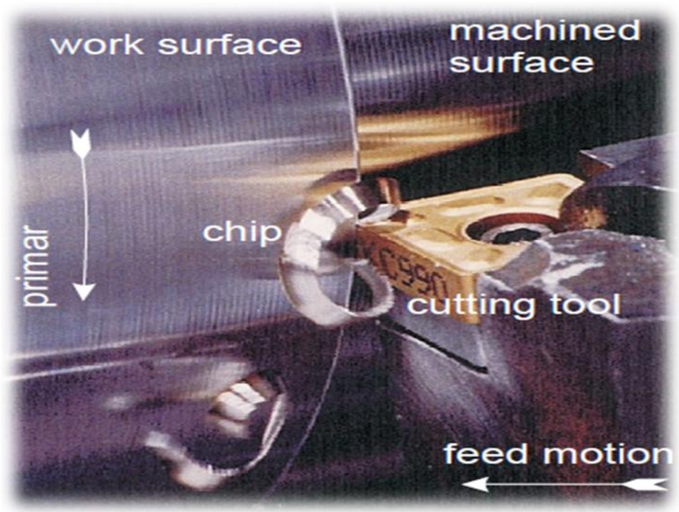


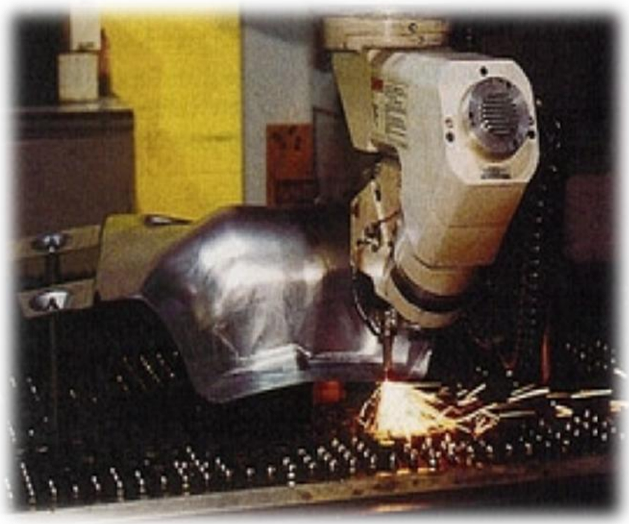
Schematic illustrations of various machining and finishing processes.

MACHINING PROCESS

3 Categories:

1. **Traditional / Conventional –** sharp cutting tool is used to mechanically cut the material to achieve the desired geometry : turning, milling and drilling
2. **Abrasive –** mechanically remove material by the action of hard, abrasive particles : grinding
3. **Non-traditional –** use various energy forms include mechanical, electrochemical, thermal & chemical : EDM, CNC etc.





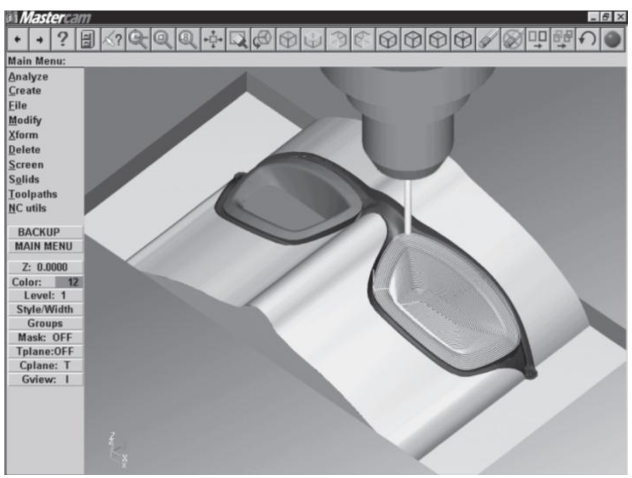
MACHINING PROCESS

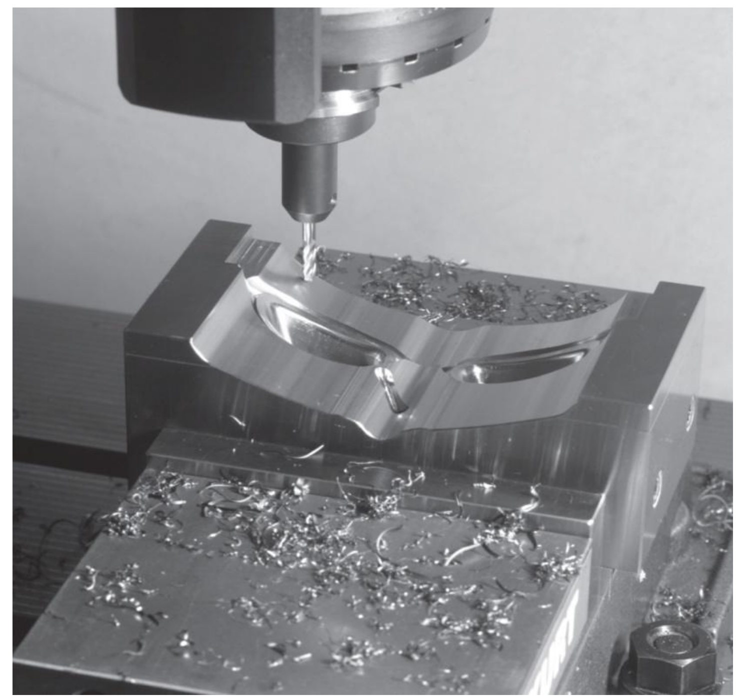
Advantages

- Variety of work materials
- Variety of part shapes and geometric features
- Dimensional accuracy
- Good surface finishes

Disadvantages

- Wasteful of material
- Time consuming





MECHANICS OF CUTTING

Major independent variables in cutting process

Factors influencing the cutting processes:

1. Tool material and coatings
2. Tool shape, surface finish and sharpness
3. Work piece material and condition
4. Cutting speed, feed and depth of cut
5. Cutting fluids & work holding
6. Characteristics of the machine tool

Major dependent variables in cutting process

Influenced by the changes in the independent variables:

1. Types of chip produced
2. Force and energy distributed during cutting
3. Temperature rise in the work piece, tool and chip
4. Tool wear and failure
5. Surface finish and surface quality of the work piece

MECHANICS OF CUTTING

Problems when machining operations yield unacceptable results such as:

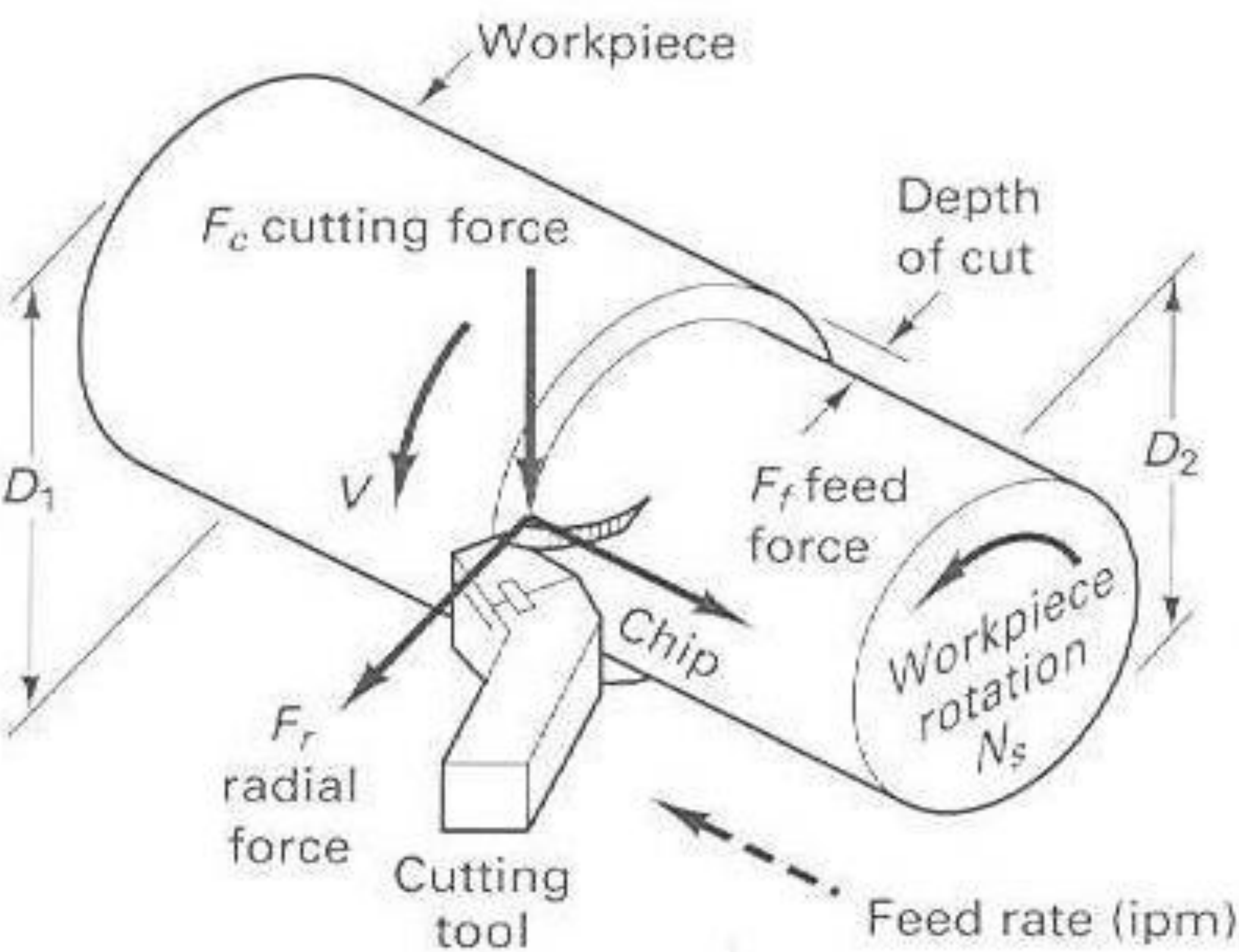
1. Surface finish of the work piece is unacceptable
2. Cutting tool wears rapidly and becomes dull
3. Work piece become very hot
4. Tool begins to vibrate and chatter

- *Require a systematic investigation – study the mechanics of cutting.*

CUTTING CONDITIONS

Elements:

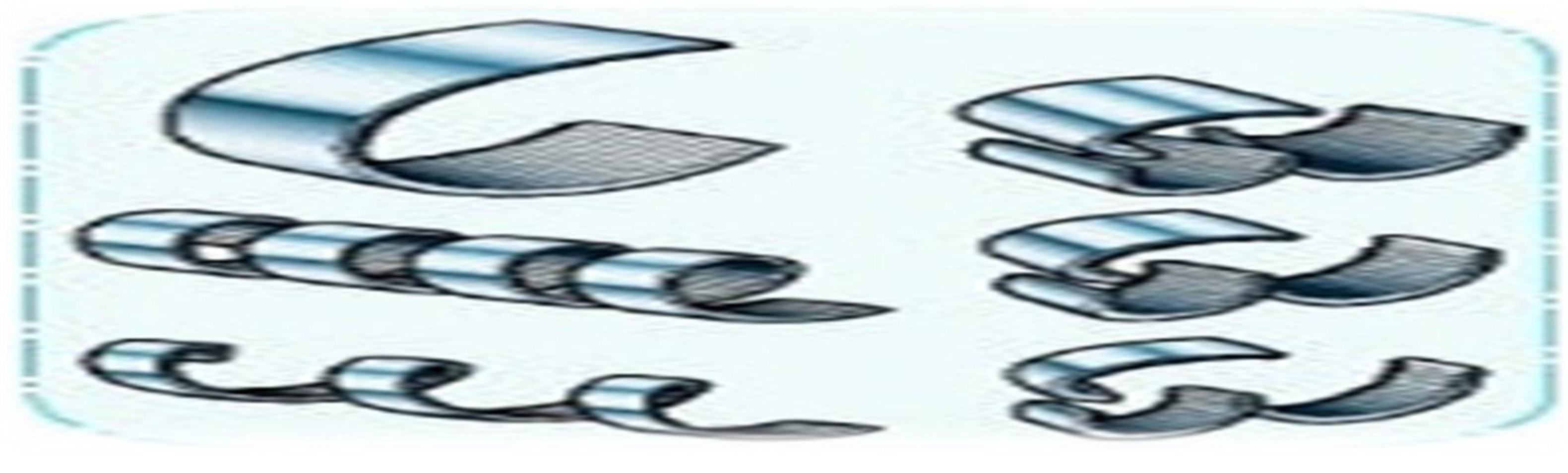
1. **<u>Cutting speed, V</u>** <u>(shown with heavy dark arrow)</u>
   - The primary cutting motion.
   - Travelling velocity of the tool relative to the work piece.
   - Measured in m/s or m/min.
2. **<u>Feed, f</u>** <u>(shown with dashed arrows)</u>
   - In turning - amount of material removed per revolution of the work piece and measured in mm/rev
   - In milling and drilling – amount of material removed per pass of the tool over the work piece and measured in mm/min
   - To machine a large surface, the tool must be given a feed.
3. **<u>Depth of cut, d</u>**
   - The distance the tool is plunged into the surface of the workpiece and measured in mm.



Workpiece
Depth
of cut
F_c cutting force
D_1
V
D_2
F_f feed
force
Chip
Workpiece
rotation
N_s
F_r
radial
force
Cutting
tool
Feed rate (ipm)

CHIP FORMATION

- Diagram shows removal of the deformed material from the work piece by a single point cutting tool.
- The movement of the tool into the work piece deforms the work material ahead of the tool face plastically and finally separates the deformed material from the work piece.
- This separated material flows on the rake face of the tool called as **chip.**
- The chip near the end of the rake face is lifted away from the tool, and the resultant curvature of the chip is called **chip curl.**

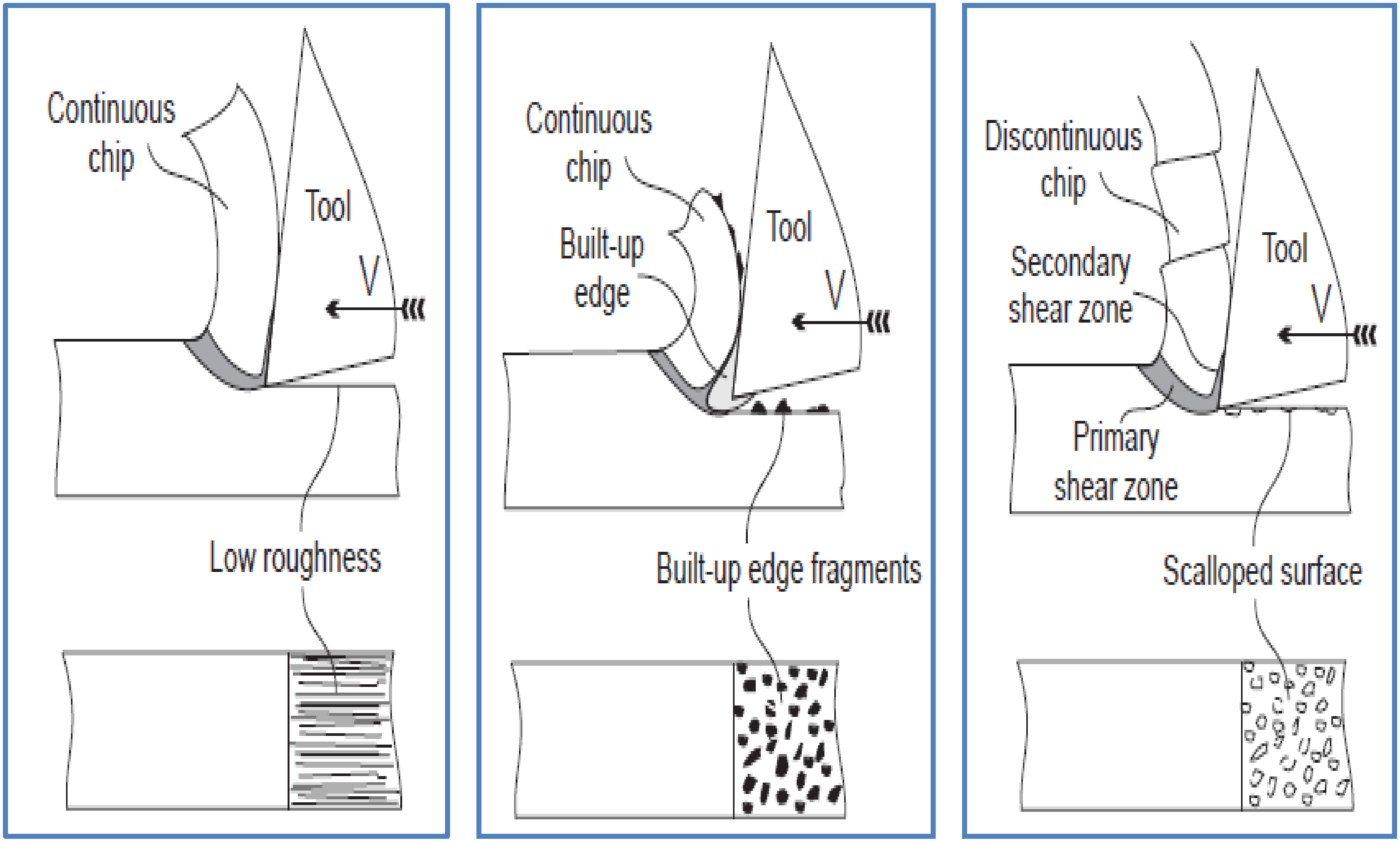


TYPES OF CHIPS

1. Continuous chips - looks like a long ribbon with a smooth and continuous shining surface; resulting in good surface finish, high tool life and low power consumption.
2. Built-up edge - a very hardened layer of work material gradually attached to the tool face; as it grows larger, it becomes unstable and breaks apart, carried away by the tool side and rest on work piece surface.
3. Discontinuous chips - comes off as small chunks or particles; it indicates brittle work material, work piece materials containing hard inclusions and impurities, very low or high cutting speeds, large depth of cut etc.

- Determined by a number of parameter:
  1. Type of tool-work engagement
  2. Work material properties
  3. Cutting conditions

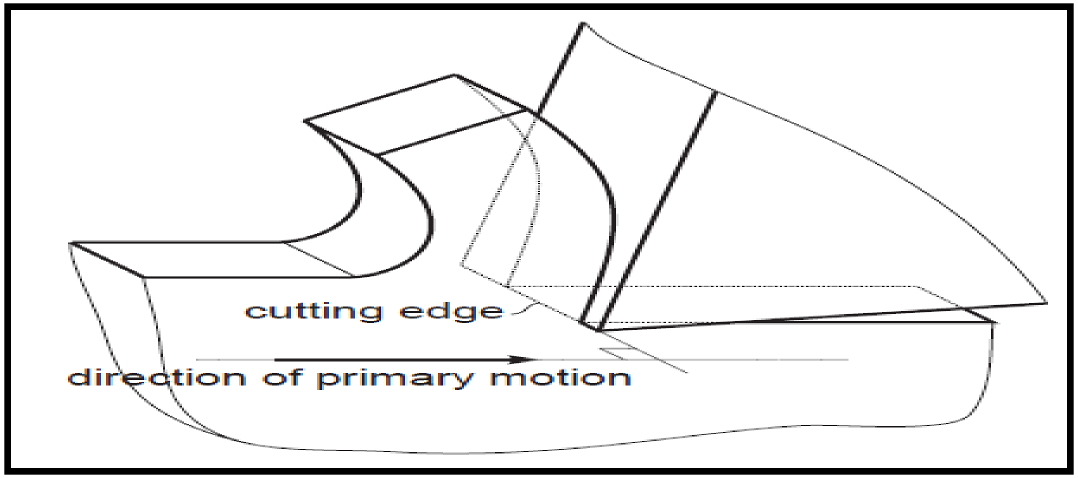
TYPES OF CHIPS



TYPES OF CUTTING

Principle Types of Cutting:

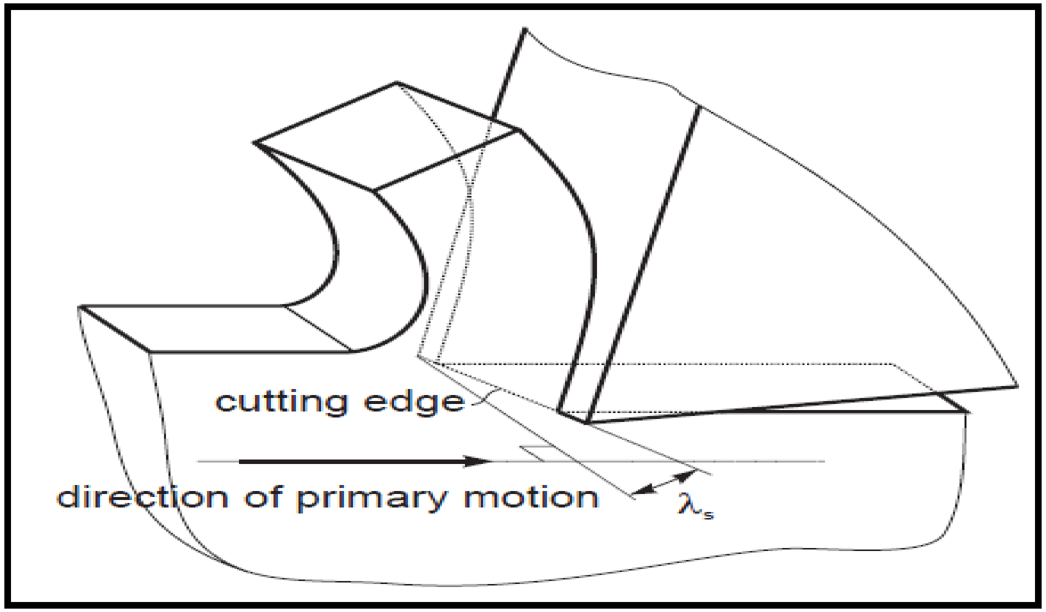
1. **<u>Orthogonal Cutting</u>**
   - Cutting edge is straight and is set in a position that is perpendicular to the direction of primary motion and the length of the cutting edge is greater than the width of the chip removed.
   - Known as Two-Dimensional (2-D) Cutting.
   - A few of cutting tools perform orthogonally e.g. lathe cut-off tools, straight milling cutters etc.



TYPES OF CUTTING

2. **Oblique Cutting**

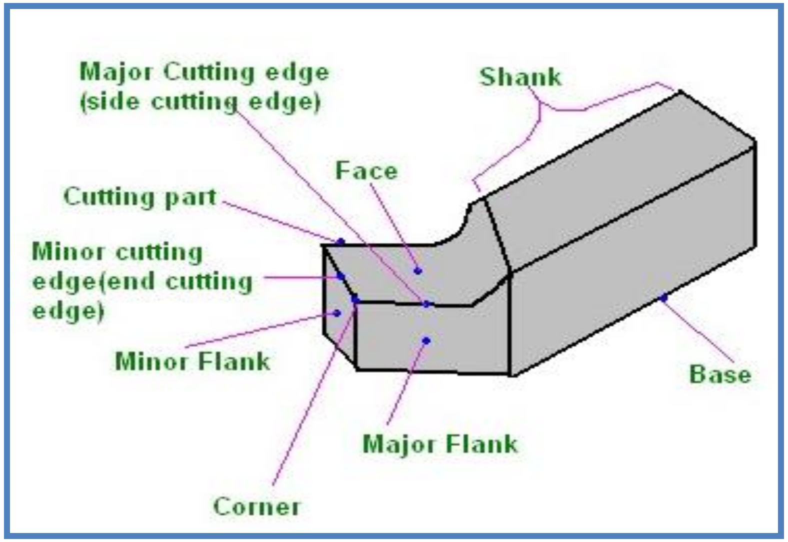
- Cutting edge is set at an angle and inclined to the cutting direction (the tool cutting edge inclination λ_s).
- Known as Three Dimensional (3-D) Cutting.
- Majority of the cutting operations perform obliquely such as turning, milling etc.



CUTTING TOOL

2 types:

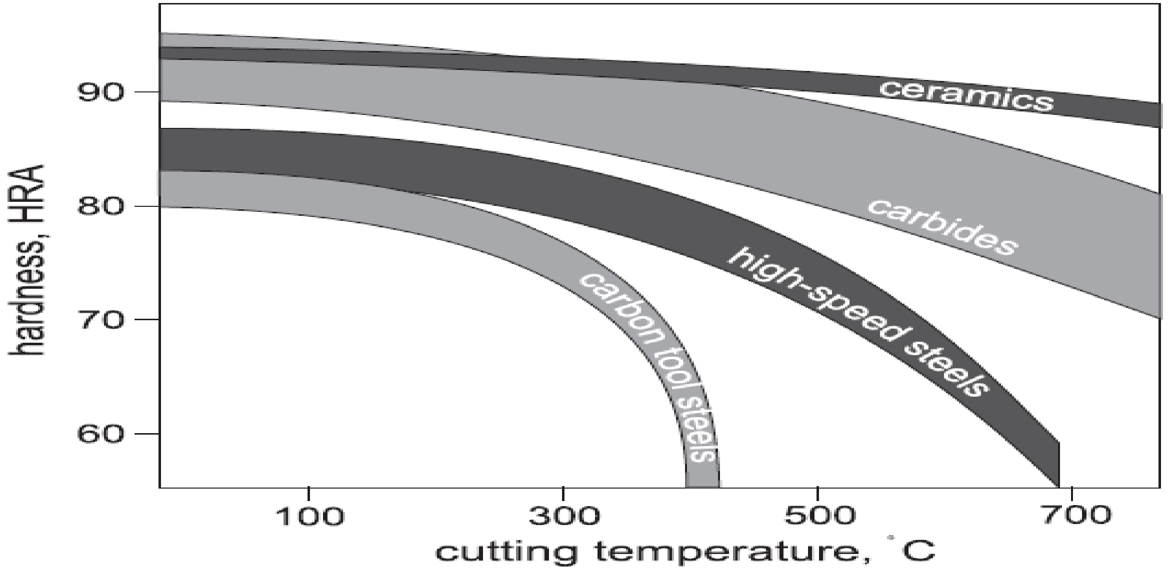
1. **Single-point cutting**
   - Cutting tool has only one major cutting edge.
   - Eg.: turning, boring.



2. **Multipoint cutting**
   - Cutting tool has more than one major cutting edge.
   - Eg.: drilling, milling, reaming

CUTTING TOOL MATERIALS

- Must possess properties to avoid excessive wear, fracture failure and high temperatures in cutting.
- Required characteristics:
  1. Hardness at elevated temperatures (so-called hot hardness) - so that hardness and strength of the tool edge are maintained in high cutting temperatures.



Hot hardness for different tool materials

CUTTING TOOL MATERIALS

2. Toughness - ability of the material to absorb energy without failing.
3. Wear resistance - depends on hot hardness, surface finish on the tool, chemical inertness and thermal conductivity of the tool material.

Types:

1. Carbon steels
2. High-speed steel
3. Cemented carbides
4. Ceramics
5. Cubic Boron Nitride (CBN)
6. Synthetic Diamonds

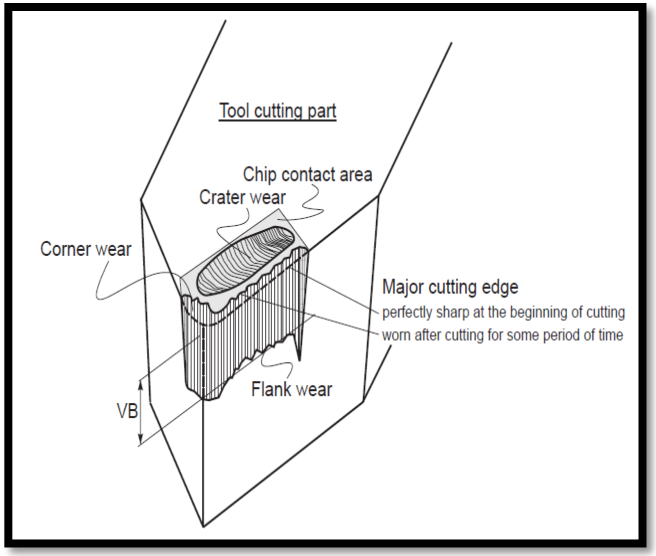
TOOL WEAR AND TOOL LIFE

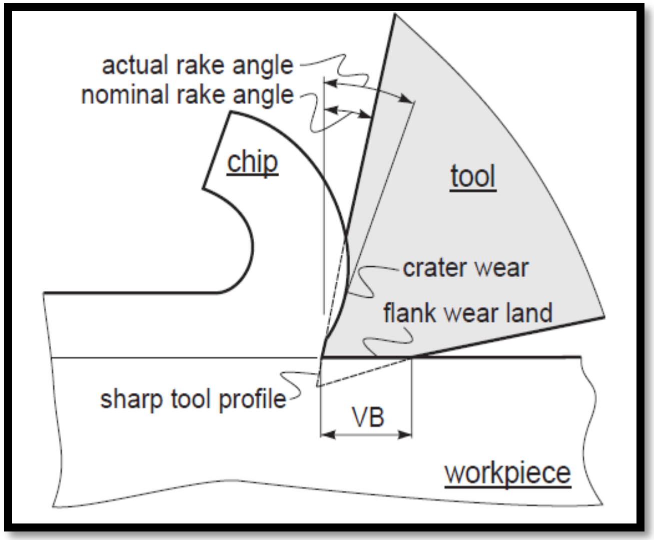
Categories of tool wear:

1. Gradual wearing of certain regions of the face and flank of the cutting tool
2. Abrupt tool failure

Options of resolving tool wear:

1. Re-sharpen the tool on a tool grinder, or
2. Replace the tool with a new one and applied when:
   a. Resource for tool resharpening is exhausted
   b. Tool does not allow for resharpening





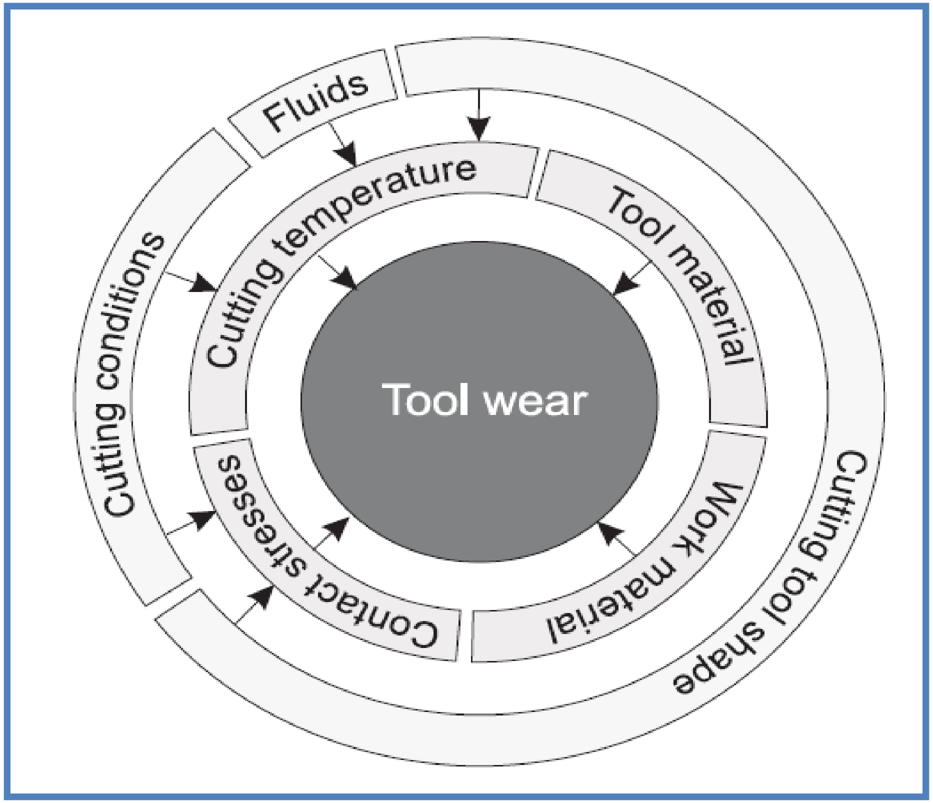
TOOL WEAR AND TOOL LIFE

Parameters which affect the rate of tool wear:

1. Cutting conditions (cutting speed V, feed f, depth of cut d)
2. Cutting tool geometry (tool orthogonal rake angle)
3. Cutting fluids

Measures to reduce the tool wear:

1. Appropriate setting of cutting conditions
2. Application of advance cutting tool materials (coated carbide, ceramics)
3. Use of cutting fluid



CUTTING FLUID

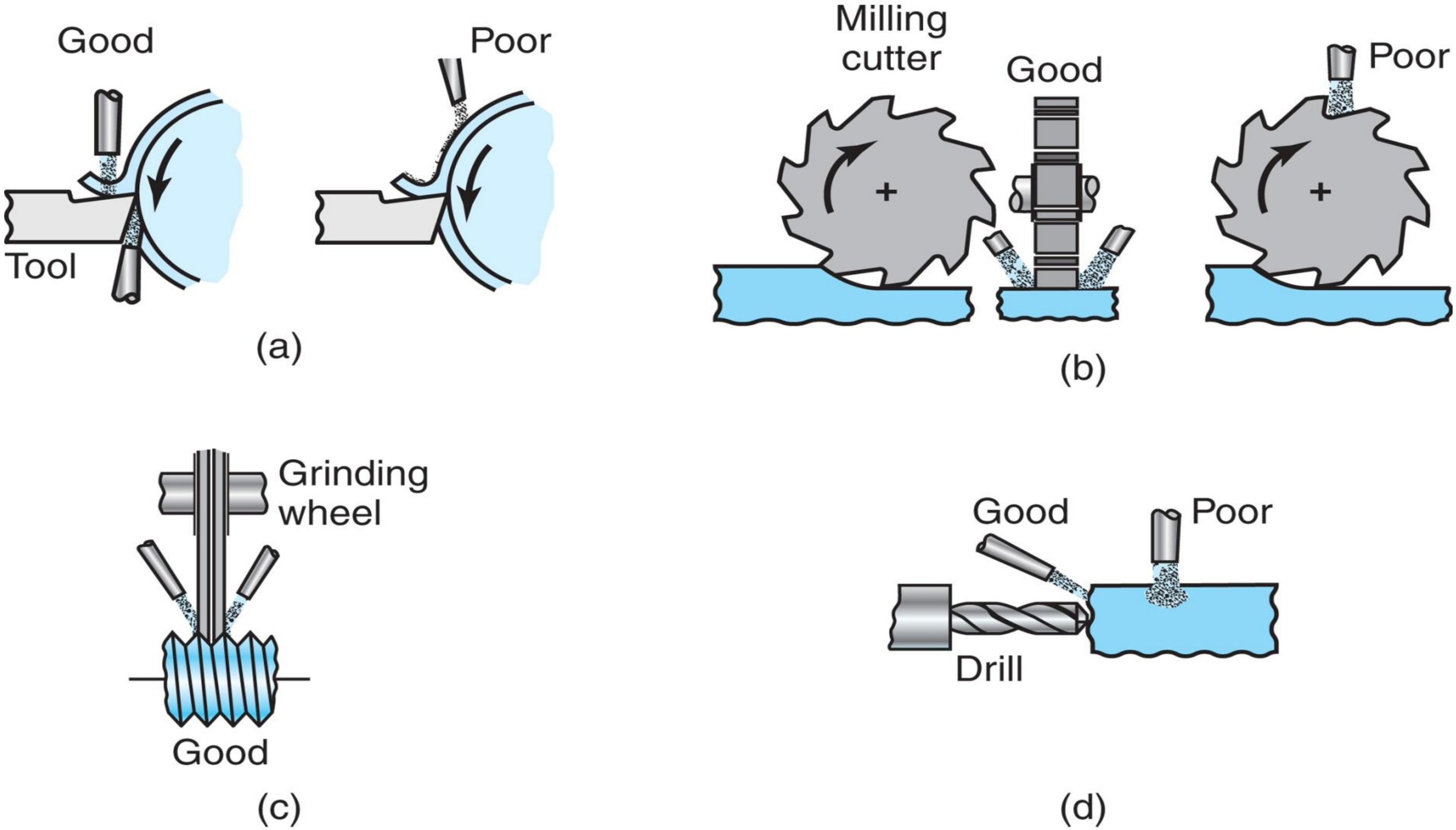
- Any liquid or gas that is applied to the chip and/or cutting tool to improve cutting performance.
- Main functions:

1. Remove heat in cutting
   - ✓ Depends on the method of application, type of the cutting fluid and the fluid flow rate and pressure.
2. Lubricate the chip-tool interface
   - ✓ Cutting fluids penetrate the tool-chip interface and reducing the friction forces and temperatures.
3. Wash away chips
   - ✓ Applicable to small, discontinuous chips only.
   - ✓ Special devices are subsequently needed to separate chips from cutting fluids.

- Types:

1. Cutting oils
2. Soluble oils
3. Chemical fluids

CUTTING FLUID



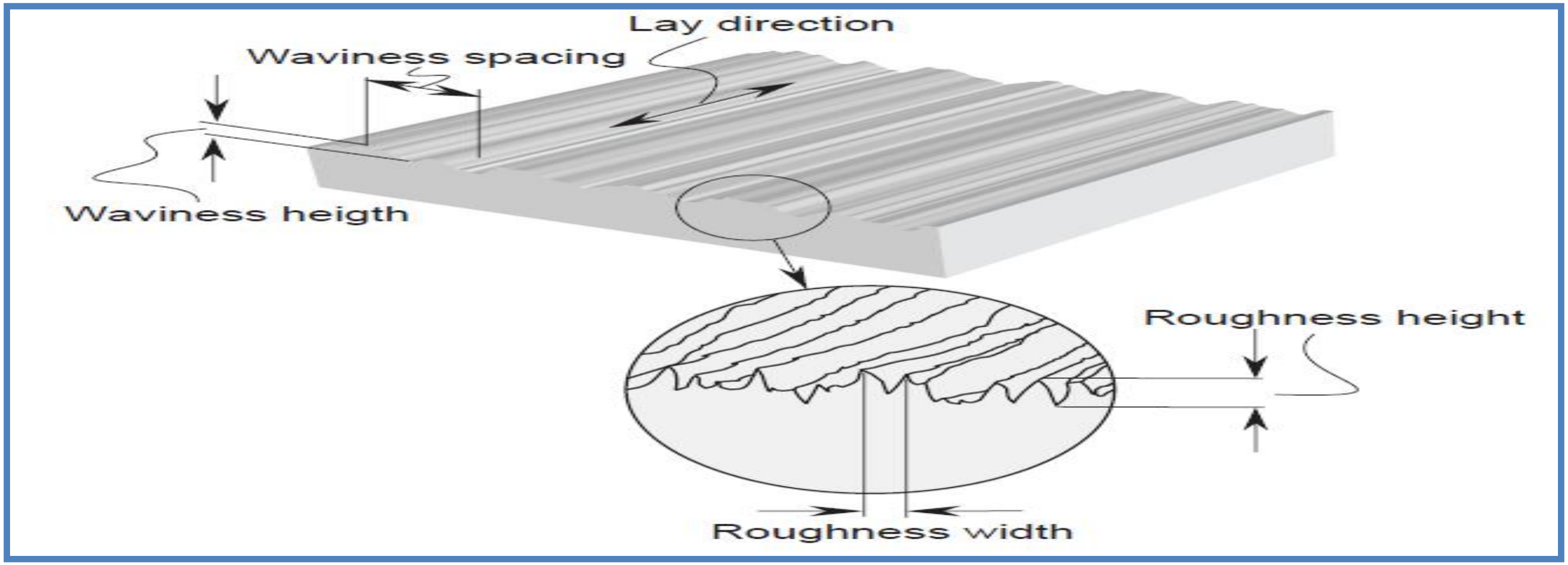
Schematic illustration of the methods of applying cutting fluids (by flooding) in various machining operations: (a) turning, (b) milling, (c) thread grinding, and (d) drilling.

SURFACE FINISH

Machining processes generate a wide variety of surface textures.

Types of surface texture:

1. Roughness - small, finely spaced surface irregularities (micro irregularities)
2. Waviness - surface irregularities of grater spacing (macro irregularities)
3. Lay - predominant direction of surface texture



SURFACE FINISH

Factors influencing surface roughness:

1. Tool geometry (major cutting edge angle and tool corner radius)

   - Increasing the tool rake angle improves surface finish.

2. Cutting conditions (cutting velocity and feed)

   - High speed and low feed provide best surface finish.

3. Work material properties (hardness)

   - Higher work material hardness results in better surface finish.
   - Tool material has minor effect on surface finish.

4. Cutting fluid

   - Cutting fluids affect the surface finish by changing cutting temperature.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