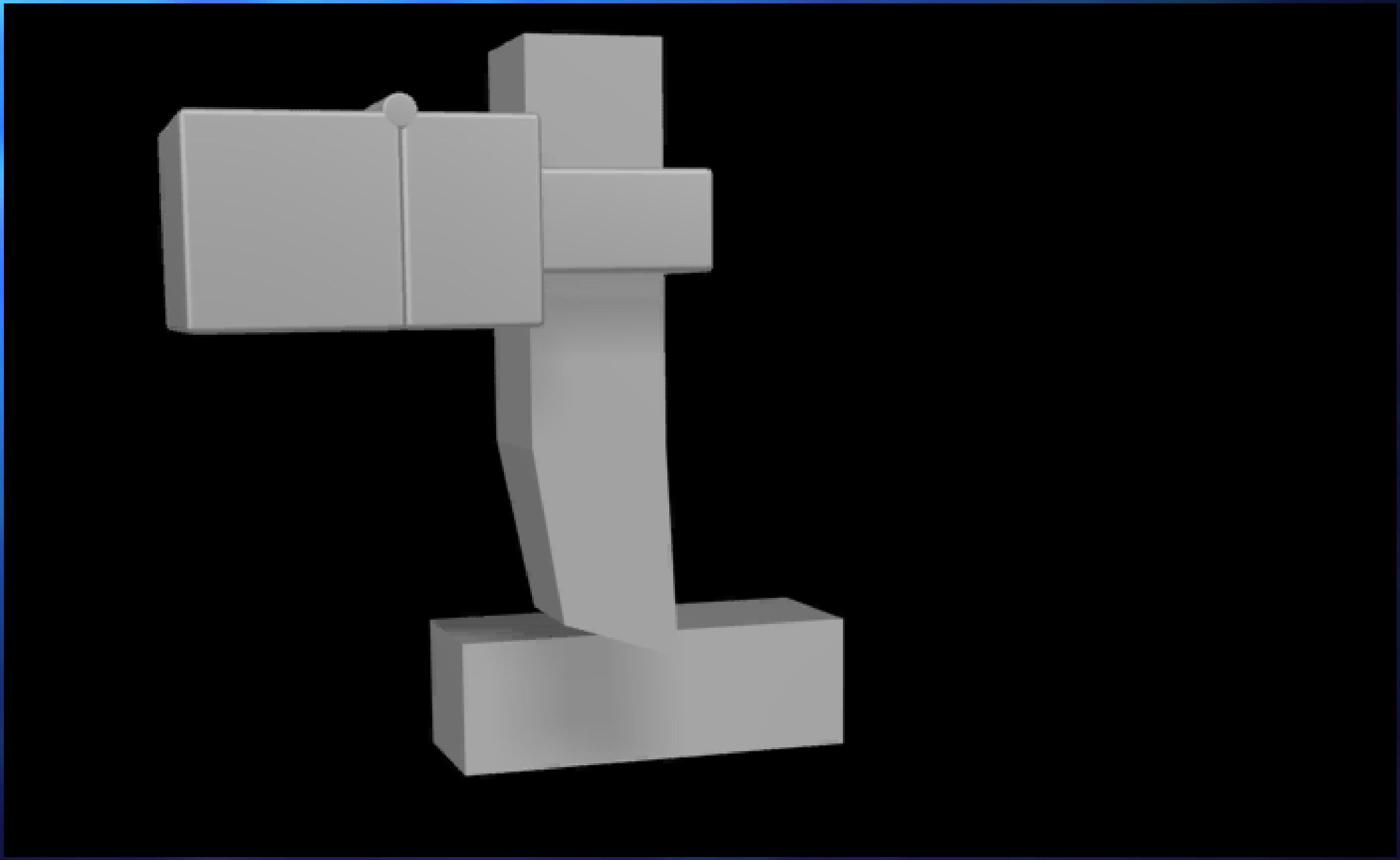
Theory of Metal Cutting

Chapter 4

Typical Metal Cutting Operation



Machining or Metal Cutting

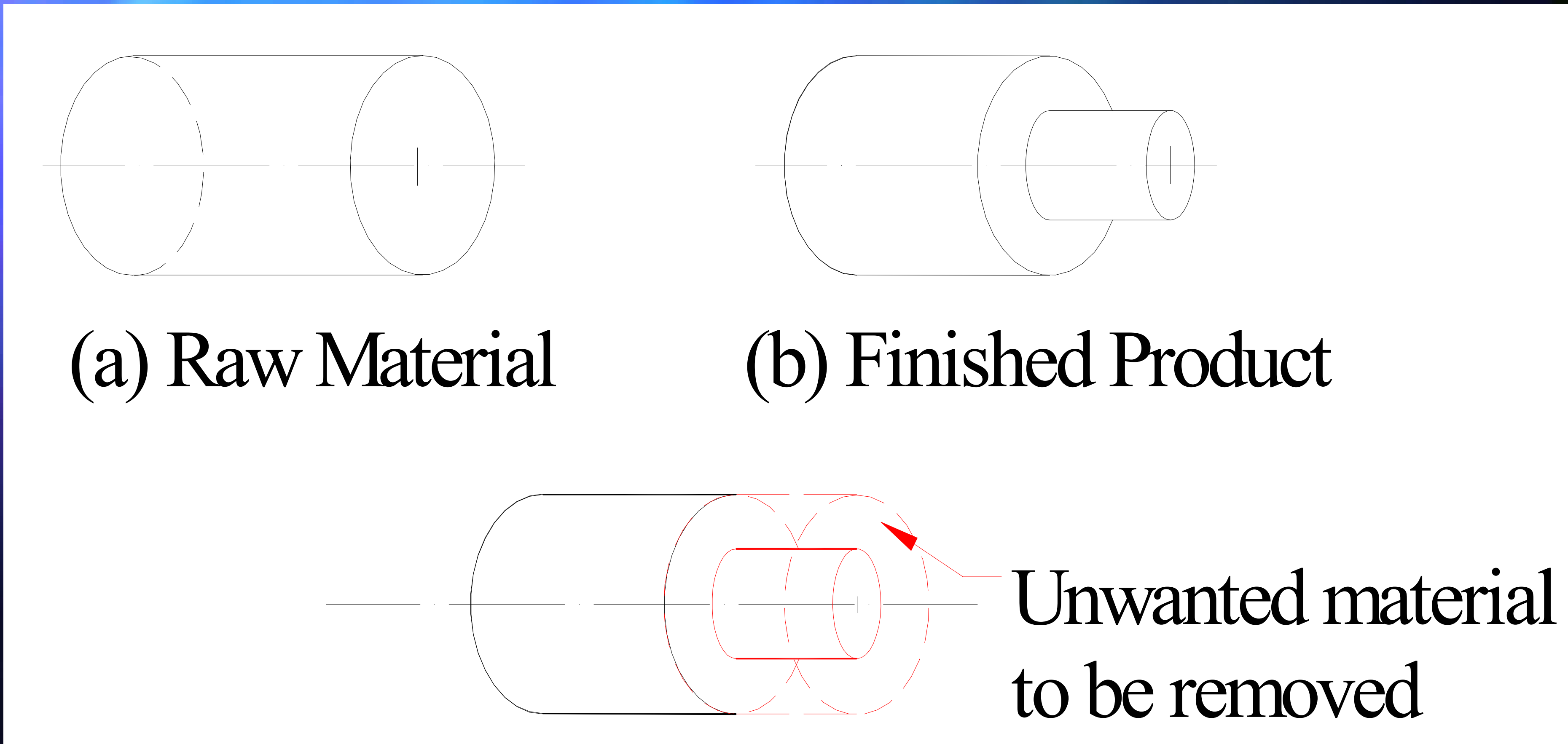
- Removing unwanted material
- Cutting/chipping/machining/ metal cutting

To get desired

- Shape
- Size
- Surface finish

Typical Machining Example

Changing shape/size/finish



Metal Cutting: features

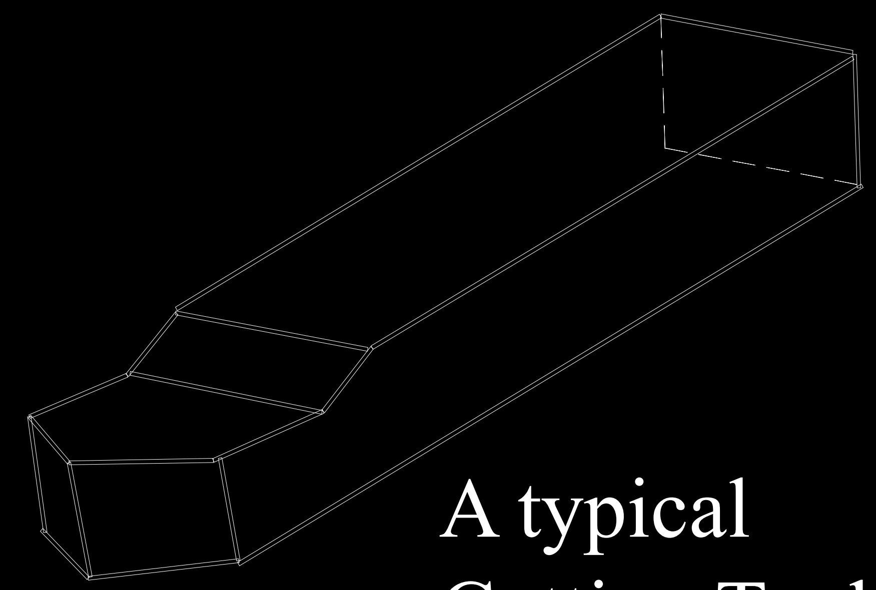
- ✓Closer dimensional accuracy
- ✓Surface texture/finish
- ✓Economical
- ✓Complex shape
- ✓Size

Metal Cutting: features

- Material loss (~50%)
- Scarcity of materials
- Special equipment
- Skilled operators
- Time required
- All materials cannot be machined

Essentials of Metal Cutting Operation

- Machine Tool
- Cutting Tool
- Method
- Operator



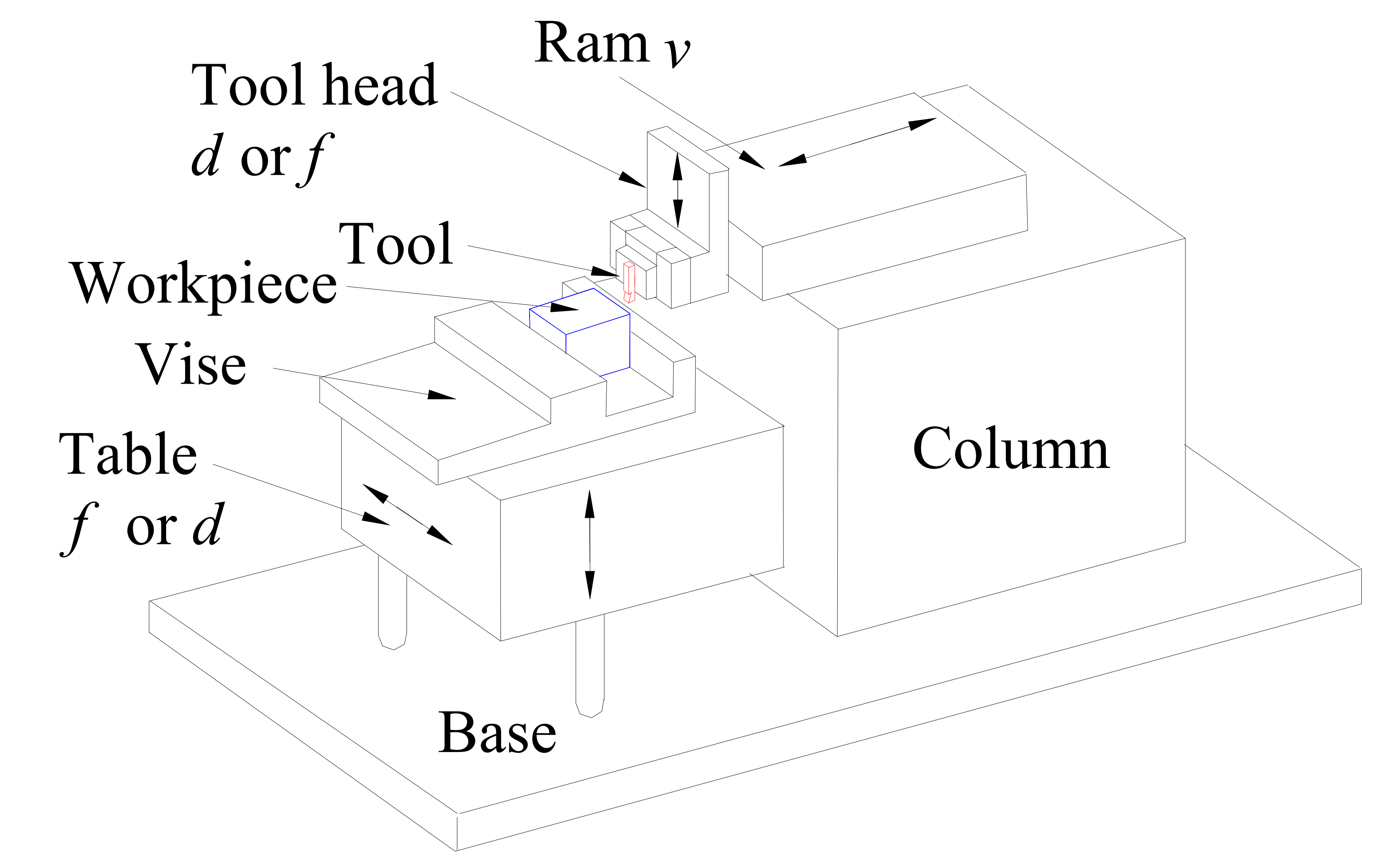
A typical Cutting Tool

Machine Tool

Machine used for metal cutting

- provision for holding workpiece
- provision for holding tool
- relative motion between them
- providing power/energy

Typical Machine tool



Different Machine Tools

Type of surface – flat/circular/complex

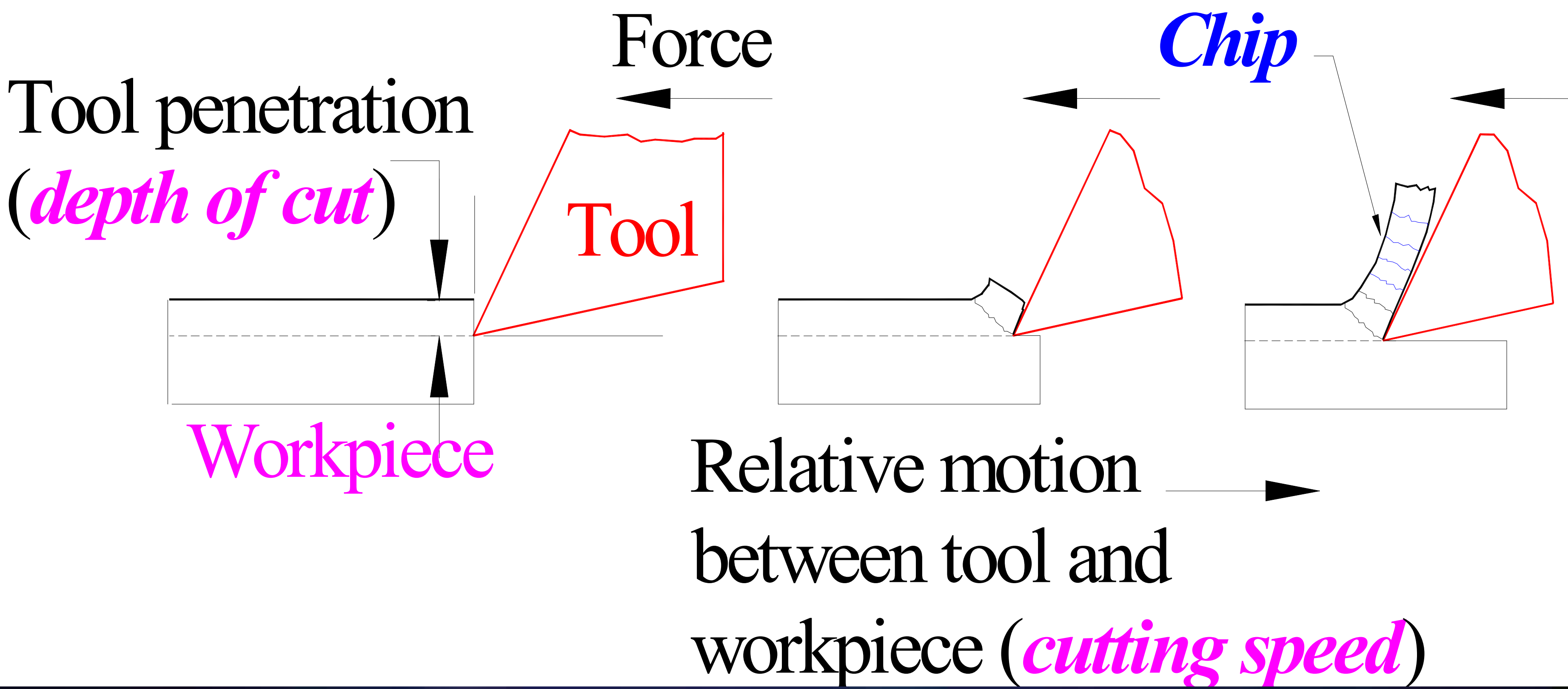
Metal Cutting Machine Tools
Metal Forming Machine Tools

Classification of Machine Tools

- **degree of specialization**
  general/special
- **motion**
  recipocatory/rotary
- **automation**
  manual/semi-auto/auto
- **surface**
  cylidrical/flat
- **duty cycle**
  L/M/H
- **energy**
  conventional/non-conventional

Mechanism of Metal Cutting

Tool & Workpiece interaction

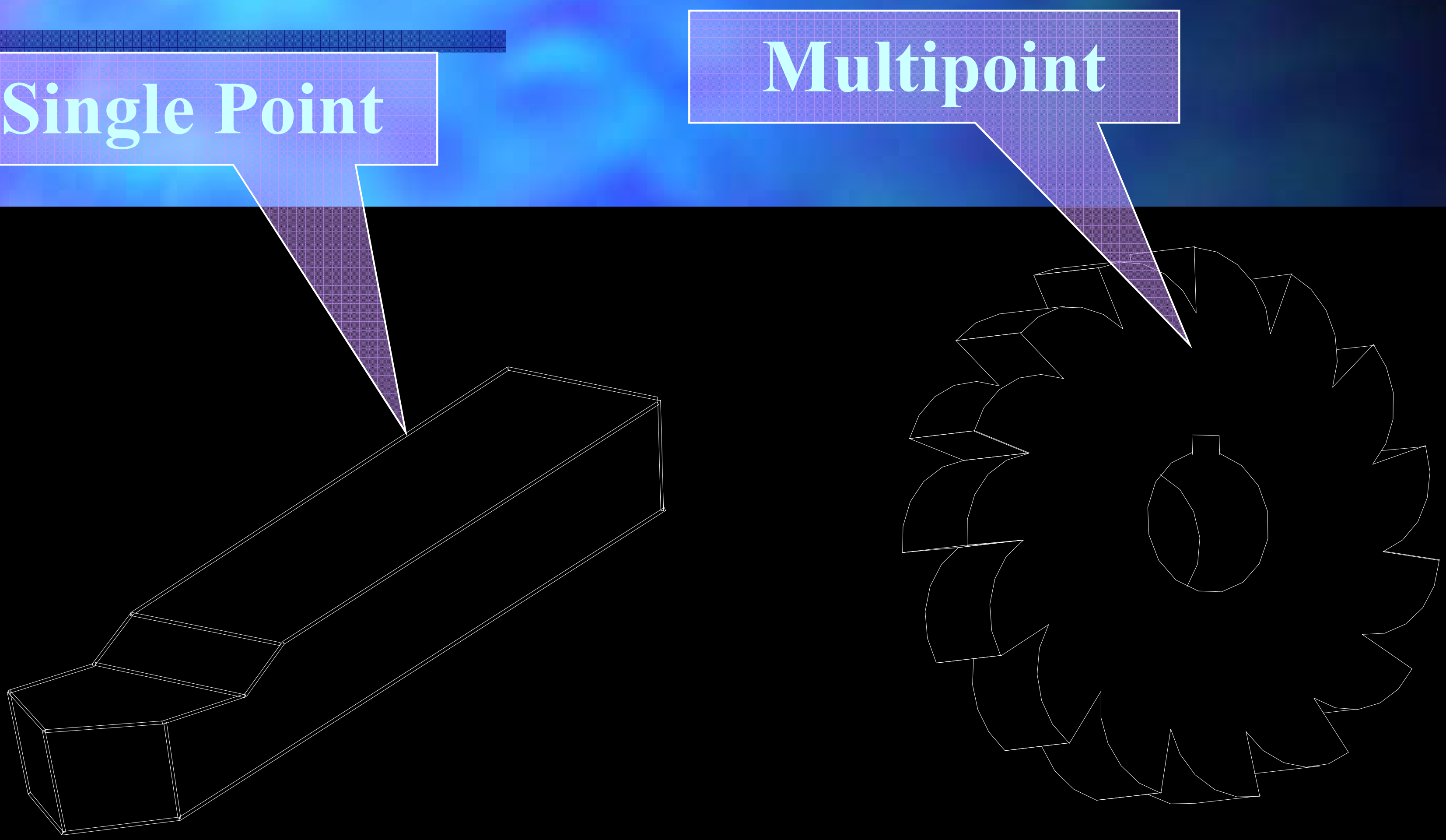


Cutting Tools

sharp edge/strong/hard/tough
shape/size/method of holding

- Requirements
- Common materials
- Alloying
- Types
- Tool geometry

Types of Tools



Metal Cutting ..

Basics

Features

Essentials

Machine Tools

Different

Classification

Mechanism of Metal Cutting

Cutting Tools

Requirements

Tool Materials

Types of tools

Geometry of Single Point Tool..

Tool Signature

8 – 14 – 6 – 8 – 8 – 19 – 1

8 – Back Rake Angle

14 – Side Rake Angle

6 – End-relief Angle

8 – Side Relief Angle

8 – End Cutting Edge Angle

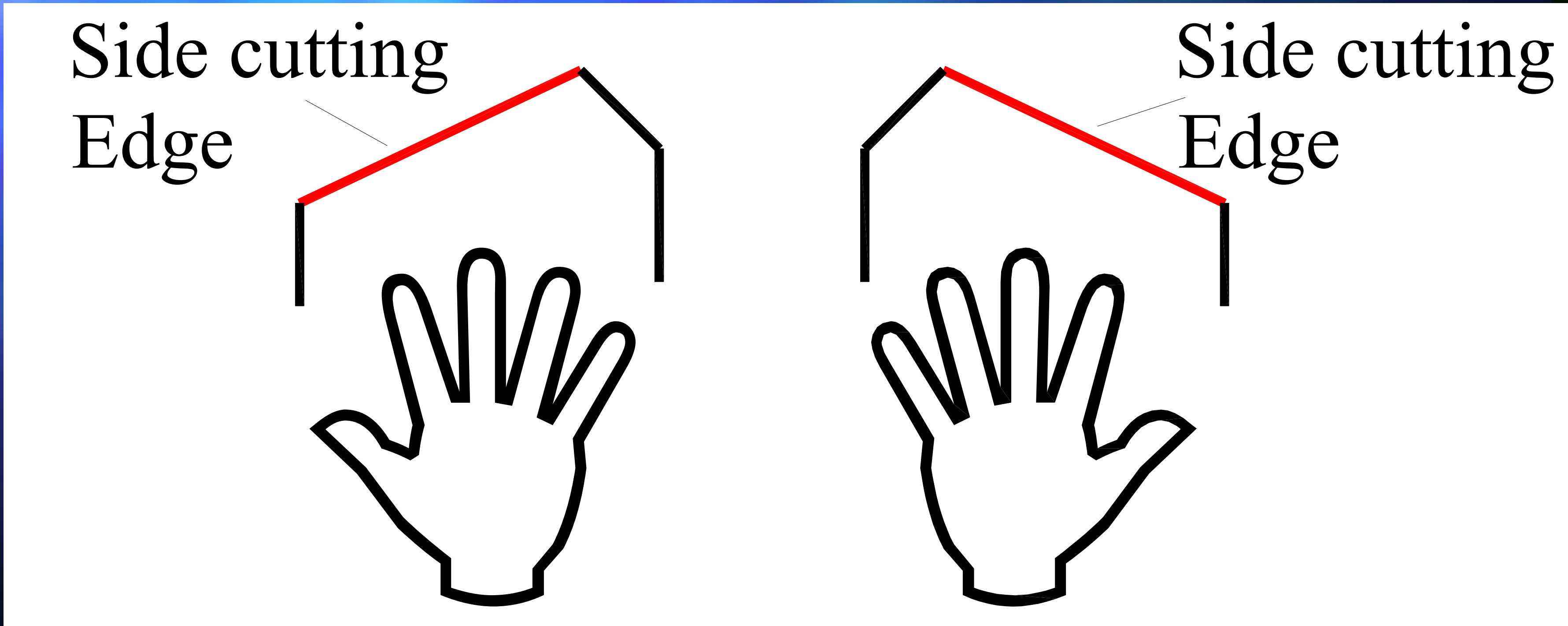
19 – Side Cutting Edge Angle

1 – Nose Radius

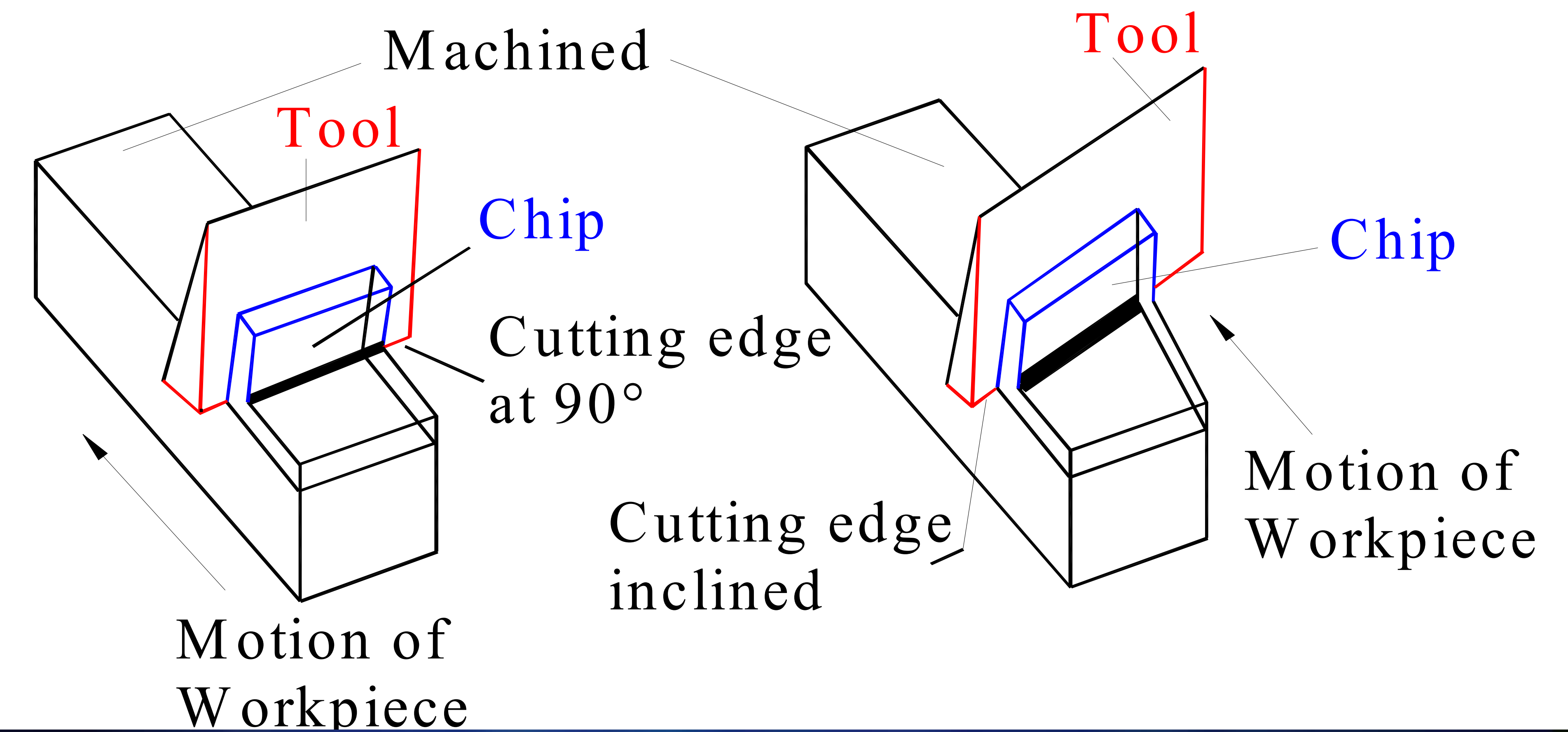
Geometry of Single Point Tool..

RH & LH Tool

Right hand tool Left hand tool

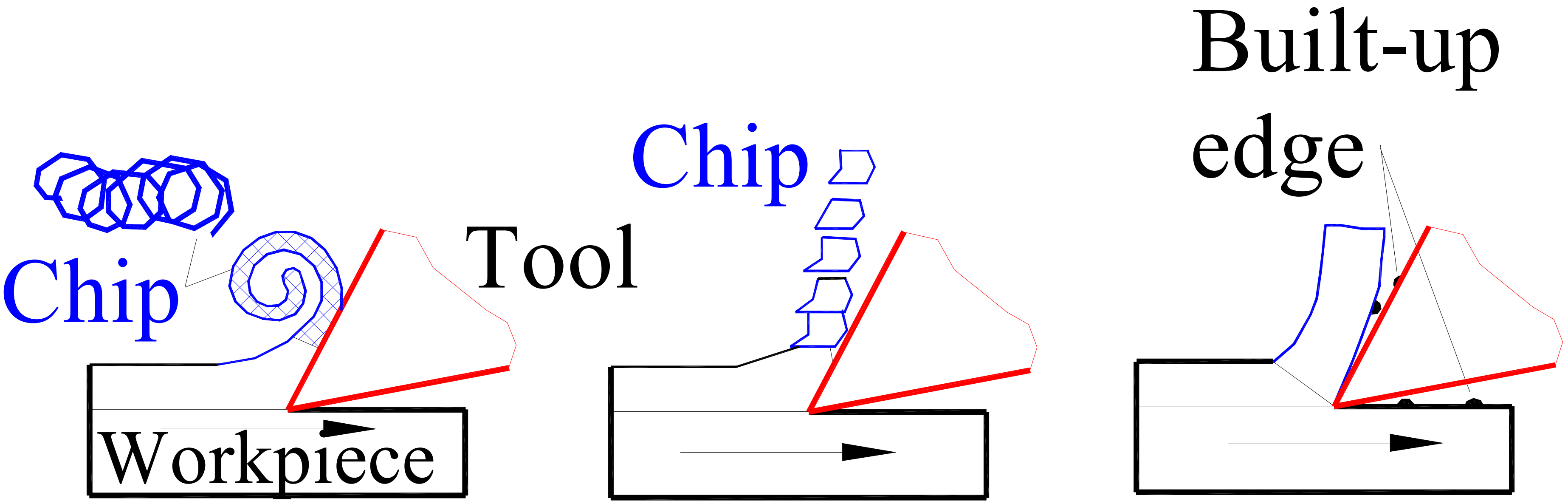


Orthogonal and Oblique Cutting



Orthogonal cutting   Oblique cutting

Types of Chips



Continuous chip

Discontinuous chip

Types of Chips ..

- Continuous Chip – chip breaker
- Discontinuous Chip
- Chip with Built-up Edge

  - Workpiece material
  - Tool geometry
  - Cutting conditions

Thermal Aspects in Machining

Heat generated in cutting operation

effects:

1. Tool
2. Workpiece
3. Machine tool
    - Surface
    - accuracy

depends:

✓ Rate of Cutting → cutting conditions

✓ Workpiece material

Thermal Aspects in Machining..
Distribution of Heat

- heat generated in machining operation ➔ chips+tool+workpiece+environment

$$Q = Q1 + Q2 + Q3 + Q4$$

$Q1$=heat taken away by the chips
$Q2$=heat conducted in to tool
$Q3$=heat conducted in to workpiece
$Q4$=heat dissipated in environment

Thermal Aspects in Machining..
Distribution of Heat..

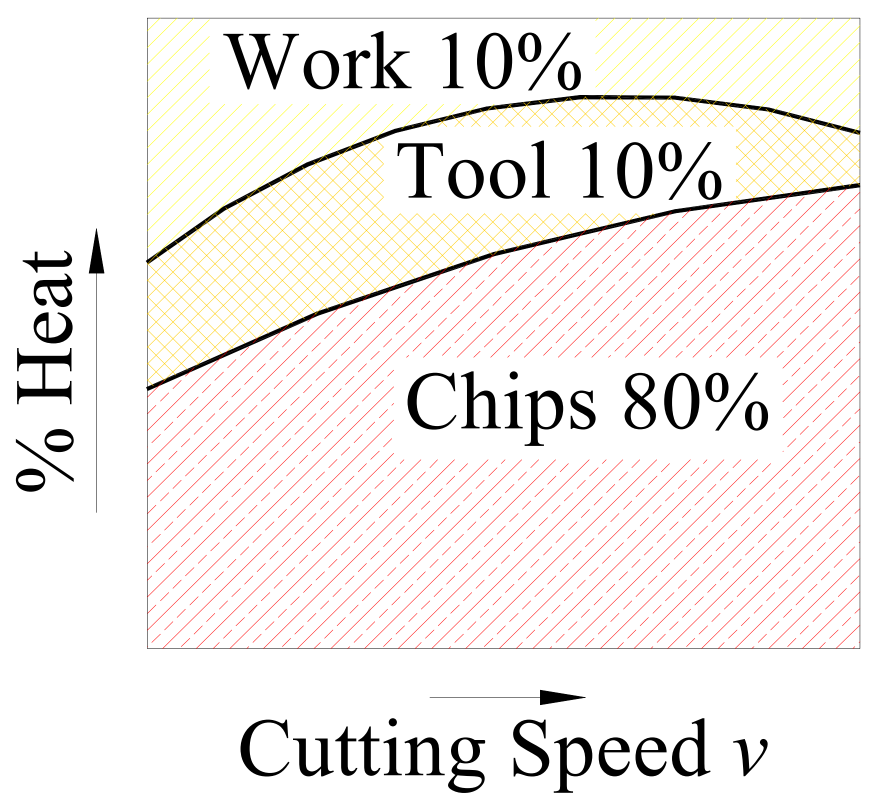
Heat dissipation

- depends on cutting speed

To keep cutting zone temperature low

→Cooling

→Cutting Fluid



Cutting Fluids

- ☑absorb and carry away the heat
- ☑cool the workpiece and tool.
- ☑reduce the friction
- ☑wash away the chips.
- ☑carry away the built-up edges formed.
- ☑give very fine surface finish
- ☑prevent corrosion

Operating Conditions

Conditions (motions) required for metal cutting to take place

Operating or *Cutting Conditions*

- Cutting Speed v – m/s
- Feed f – mm/s or mm/rev or mm/min
- Depth of Cut d – mm
- Material Removal Rate *MRR* – m^3/s
- Machining/Cutting Time

Tool Life

Wear of sharp edge → dull tool

time between two successive resharpenings

Time for which tool cuts effectively

Influencing Factors

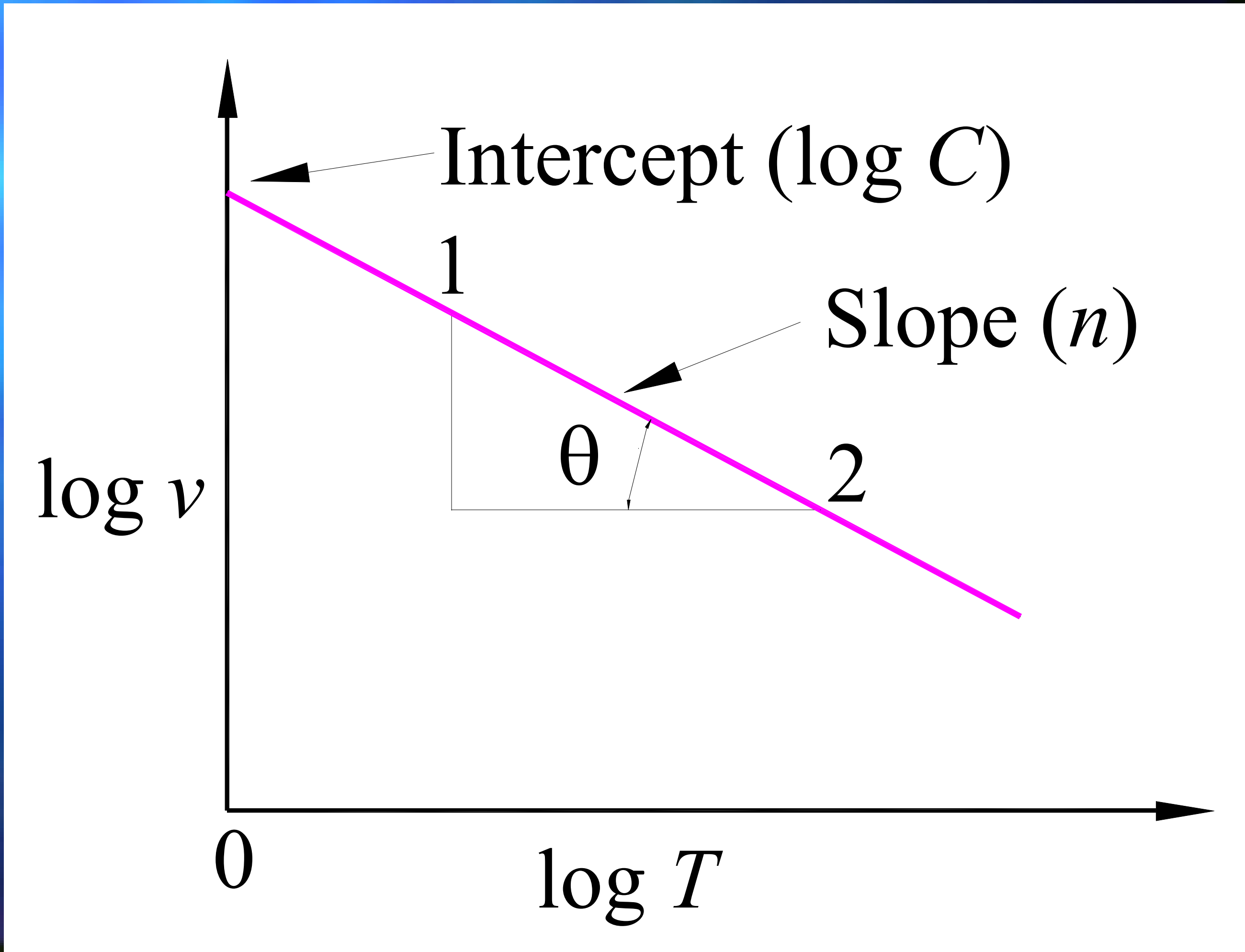
1. Operating/cutting conditions
2. Workpiece material
3. Tool material
4. Geometry of tool
5. Use of Coolant

Tool Life ..

Cutting Speed (*v*)

tool life (*T*)

Taylor's Expression or Tool Life Equation



Tool Life..

Taylor's Expression

$$vT^n = C$$

v = Cutting Speed (m/min)

T = Tool Life (min)

n, C are constants. C = Intercept

n = Slope of line

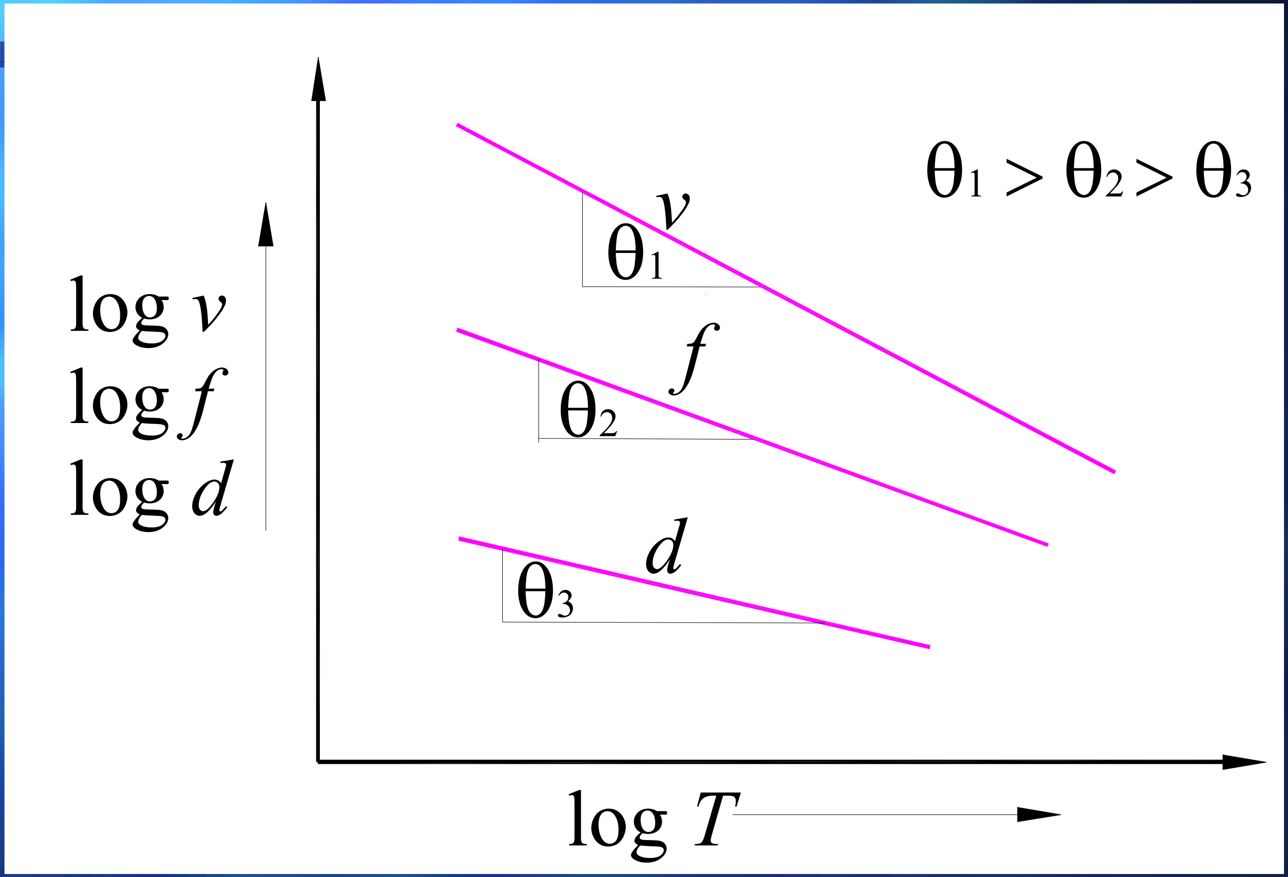
$$n = \tan\theta = \frac{\log v_1 - \log v_2}{\log T_1 - \log T_2}$$

Tool Life..
Typical n & C VALUES

Work material	Tool material	*n*	*C*
Steel	HSS	0.1-0.16	160-190
	Carbide	0.18-0.2	220-290
Cast Iron	HSS	0.08-0.1	100-180
	Carbide	0.2-0.28	250-325

Tool Life..

Effect of depth of cut and feed on tool life



$$vT^{n} f^{n_1} d^{n_2} = C$$

Machinability

Ease of machining

- Tool life
- Cutting Speed
- Force/power
- Accuracy/finish

A relative measure

- Cutting Forces/power
- specific cutting speed – CS for tool life T

Machinability ..

Machinability= (v_t / v_s) x 100%

v_s – specific CS for standard material

v_t – specific CS for test material

Machinability is affected by

- Condition of machine/tool
- Cutting conditions
- Type of operation
- work material

EXAMPLE 4.1

While machining carbon steel by a tungsten based steel tool, tool life of 50 minutes was observed when machined with a cutting speed of 100 m/min. Determine

(a) General Taylor's tool life equation and
(b) tool life for a cutting speed of 80 m/min. Assume n = 0.09.

Work material: carbon steel

Tool material: tungsten based tool steel

EXAMPLE 4.1 ..
Solution

Given: $v = 100$ m/min, $T = 50$ min, $n = 0.09$

Taylor's Eqn. $vT^n = C$

or $\log v + n \log T = \log C$

or $\log 100 + 0.09 \log 50 = \log C$

or $C = 142.20$

Hence: $vT^{0.09} = 142.2$

EXAMPLE 4.1 ..
Solution

(b)

Given: $vT^{0.09} = 142.2$, v = 80 m/min,

T = ?

$$80 \, . T^{0.09} = 142.2$$

or $T = 596.57$ min

EXAMPLES

- ***Example 4.3*** A carbide-cutting tool when machined with mild steel workpiece material at a cutting speed of 50 m/min lasted for 100 minutes. Determine the life of the tool when the cutting speed is increased by 25%. At what speed the tool is to be used to get a tool life of 180 minute. Assume n = 0.26 in the Taylor's expression.

EXAMPLES

- ***Solution:*** Given data: $v1$ = 50 m/min, $T1$ = 100 min, n = 0.26

  For 20% higher speed

  $v2$ = 1.25 $v1$ = 62.5 m/min

  We know that v1 T1^n = v2 T2^n

  Substituting the values, we get

  $T2$ = 42.39 minutes

EXAMPLES

(b) Let v_3 be the cutting speed for tool life of 180-min.

We know that

$$v_1 T_1^n = v_3 T_3^n$$

Substituting the values, we get

v_3 = 42.91 m/min

EXAMPLES

- ***Example 4.4*** In assessing machinability of different workpiece materials, the following data were obtained during machining:

Work mat	Tool life	Cutting speed
A	25	100
	10	150
B	40	200
	20	250

EXAMPLES

- Estimate the relative machinability, considering material A as standard material and tool life as cutting speed of 50 m/min as criteria.

- ***Solution*** Consider material A
- $V1=100$ m/min. $t1=25$ min $V2=150$ m/min $t2=10$ min.

- We know that
- $\log V + n \log t = \log C$

EXAMPLES

- Substituting we get
- $\log 100 + n \log 25 = \log C$

  $\log 150 + n \log 10 = \log C$

- Solving equations (1) and (2), we get
- $n = 0.43$ and $C = 403.55$
- Hence, tool life equation is $V t^{0.43} = 403.55$

EXAMPLES

- To find speed at $t = 50$ min.
- Substitute $t = 50$ min equation (3) we get $V60 = 75$ m/min.
- Repeating the same procedure for material B we get
- n=0.33 , C=631 and $V60$ = 173.53 m/min.
- Relative machinability = [$V60$ for test material / $V60$ for standard material] × 100
- = [173.53/75] × 100
- = 231.37%