ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΑΤΡΩΝ
UNIVERSITY OF PATRAS

ΑΝΟΙΚΤΑ ακαδημαϊκά μαθήματα ΠΠ

Μηχανουργική Τεχνολογία Ι

"Διεργασίες Παραγωγής"

Καθηγητής Γεώργιος Χρυσολούρης
Πολυτεχνική Σχολή
Τμήμα Μηχανολόγων & Αεροναυπηγών Μηχανικών

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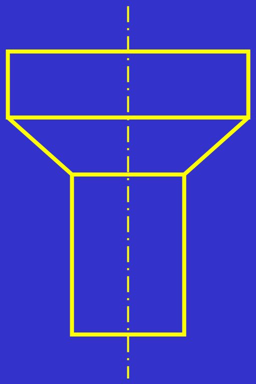
Manufacturing Processes I

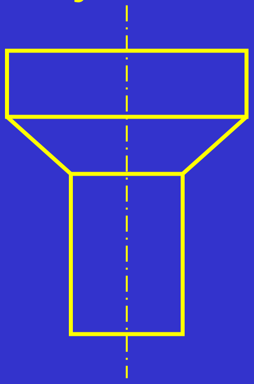
"Manufacturing Processes"

Professor George Chryssolouris
School of Engineering
Dept. of Mechanical Engineering & Aeronautics

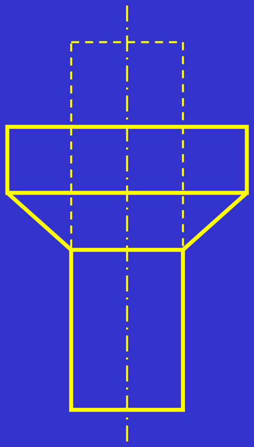


How to manufacture a bolt?

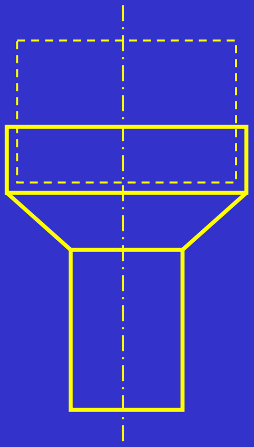
1. Casting
(primary formation)



2. Upsetting or extrusion (deformation)

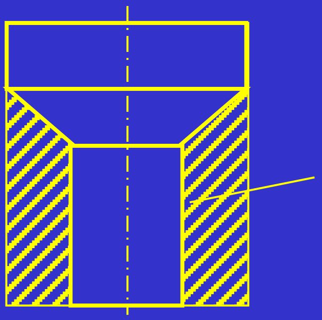


Smaller original cross section



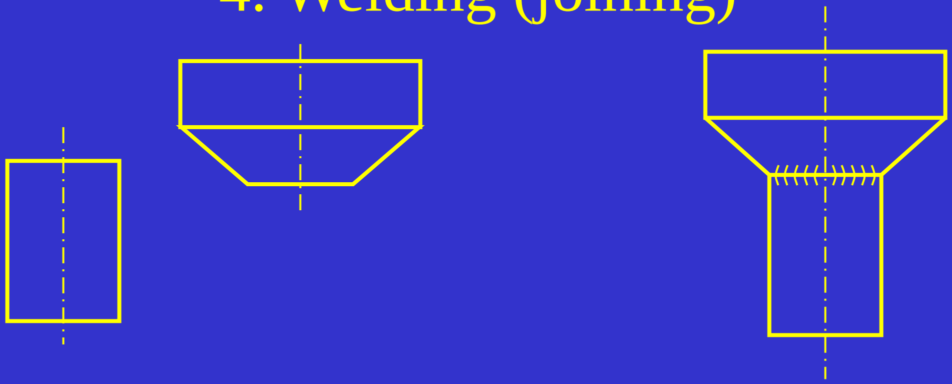
Larger original cross section (material is squeezed through a nozzle)

3. Turning (separation)



Waste

4. Welding (joining)



Manufacturing Processes

- *Forming or primary processes* create an original shape from a molten or gaseous state, or from solid particles. During primary forming processes, cohesion is usually created among particles.
- *Deforming processes* convert the given shape of a solid to another shape without changing its mass or its material composition. cohesion is maintained among particles.
- *Removing processes* remove material during the process itself, destroying cohesion among particles.

Manufacturing Processes

- *Joining processes* unite individual workpieces to make subassemblies or final products. This class of process, which includes additive processes such as filling and impregnating of workpieces, increases cohesion among particles.
- *Processes that change material properties* of a workpiece in order to achieve desirable characteristics.

Table 2.1

PROCESSES

MATERIALS	Forming	Deforming	Removing	Joining	Changing
Metals	××	××	××	××	××
Ceramics	××	–	×	–	–
Polymers	××	×	×	×	–
Composites	××	–	×	–	–

××: widely used, ×: seldom used, –: not used

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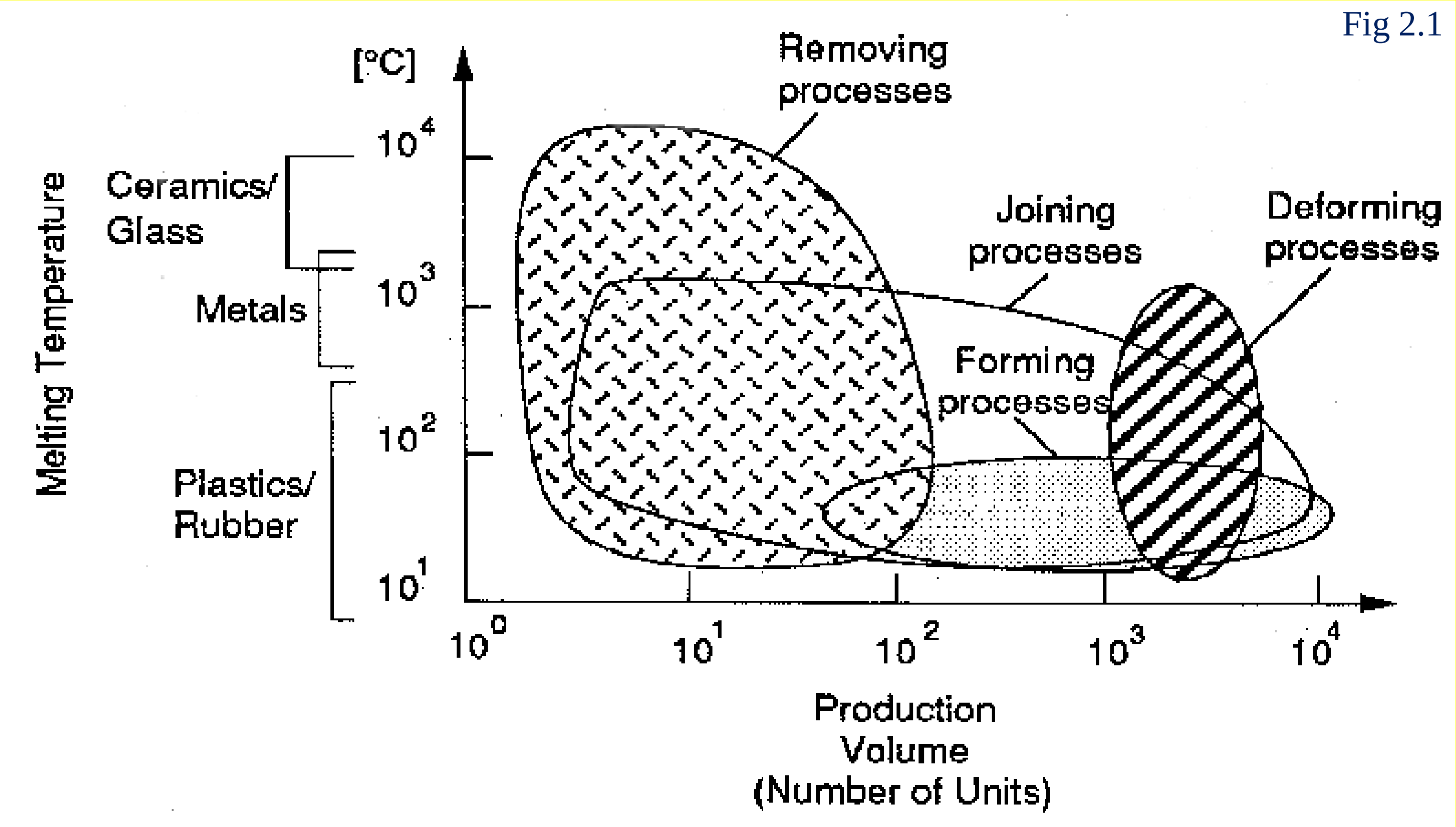
Influence of Melting Temperature and Production Volume on Manufacturing Process Selection



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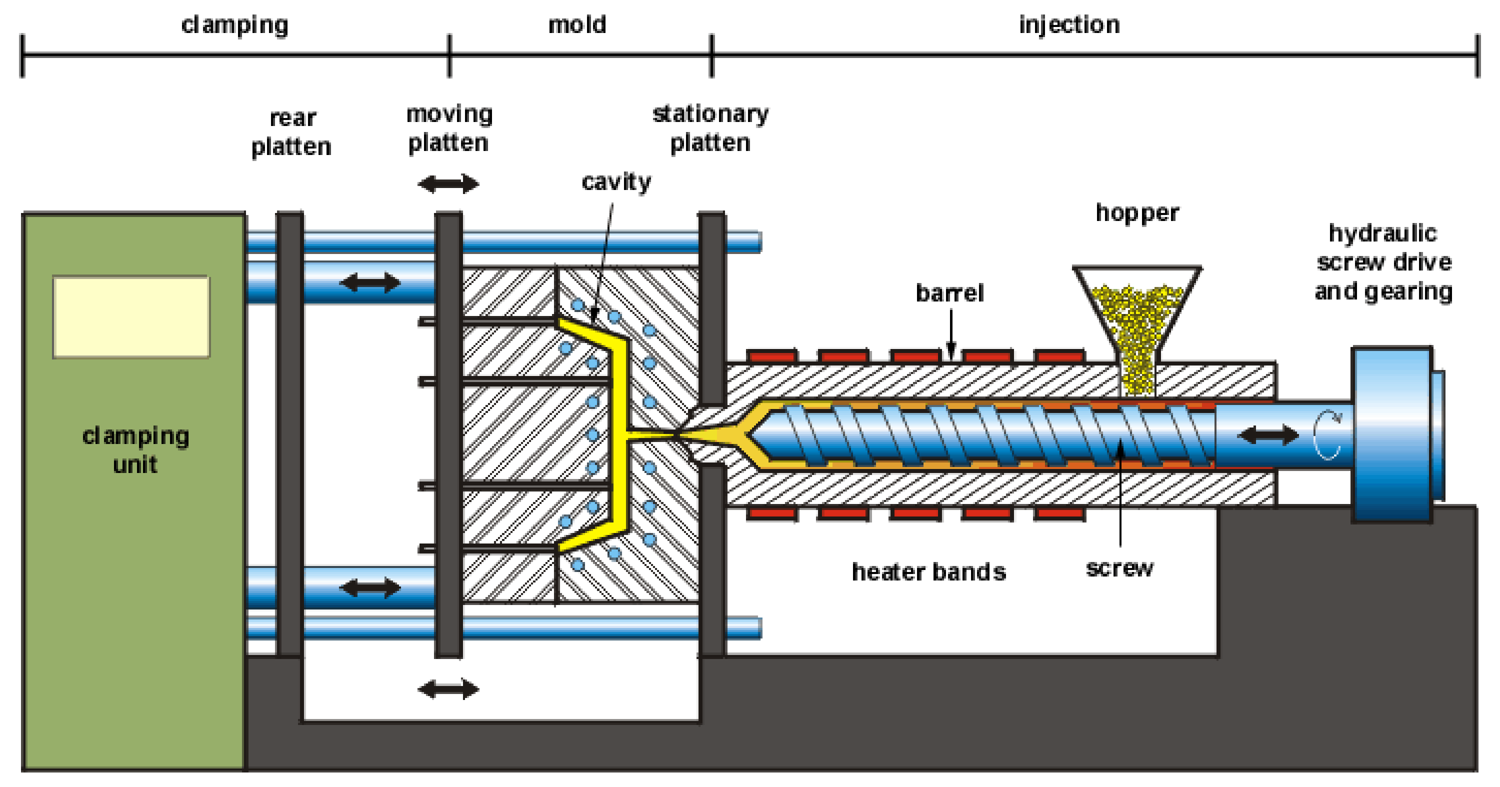
Injection Molding

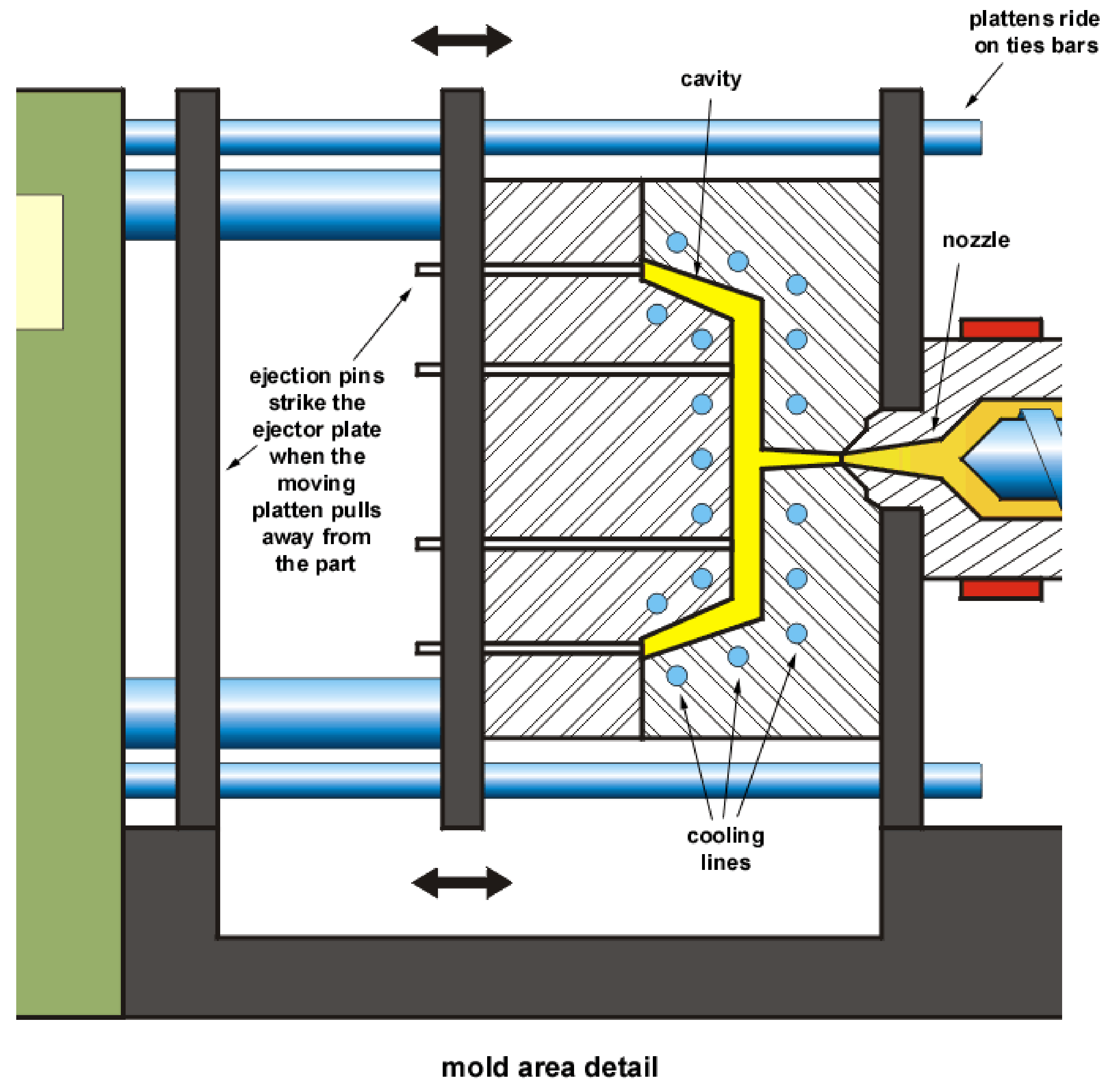
The injection molding process is used to produce plastic complex parts.



schematic of thermoplastic injection molding machine

Injection Molding

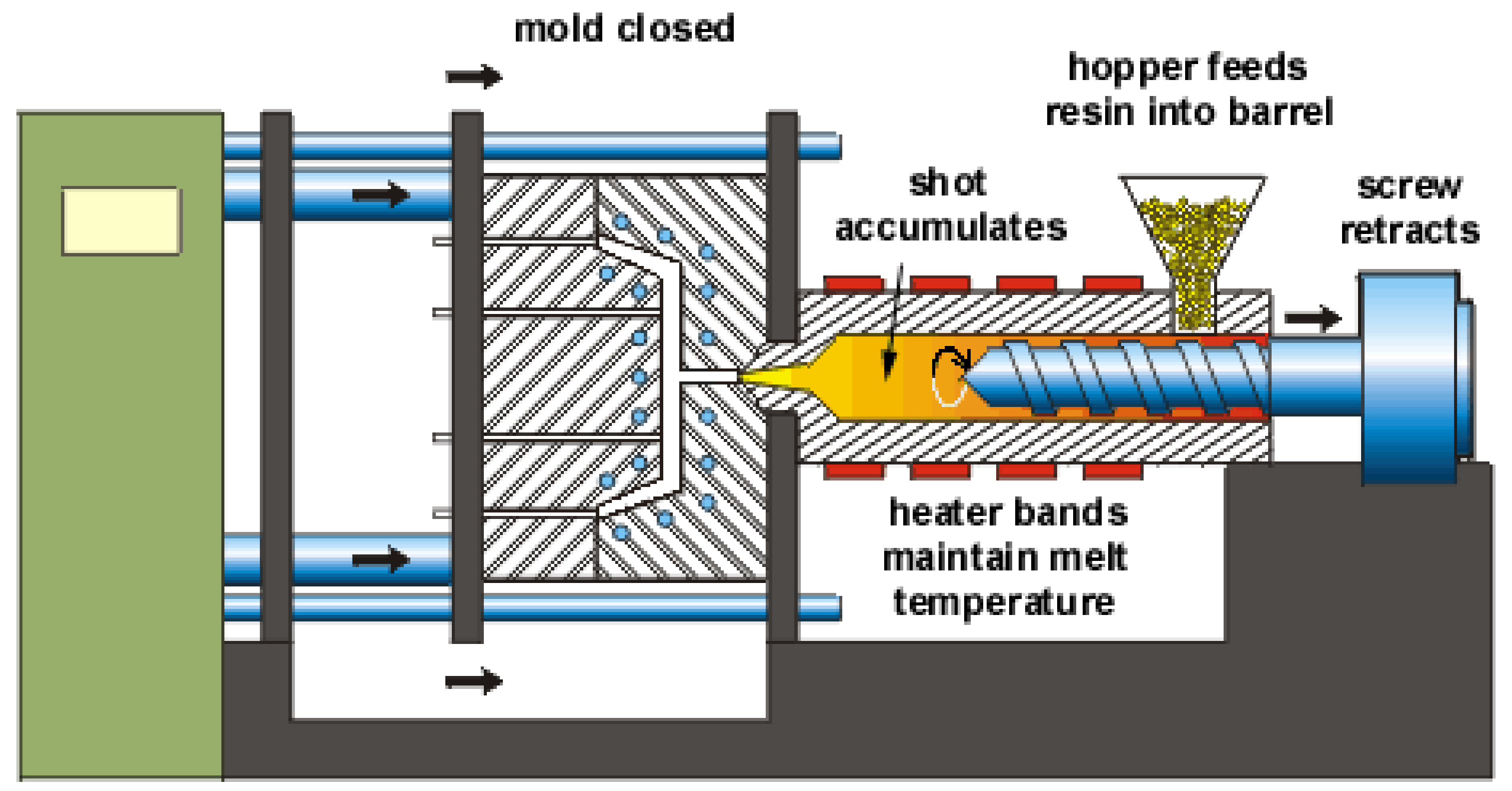
Close look of a mold



mold area detail

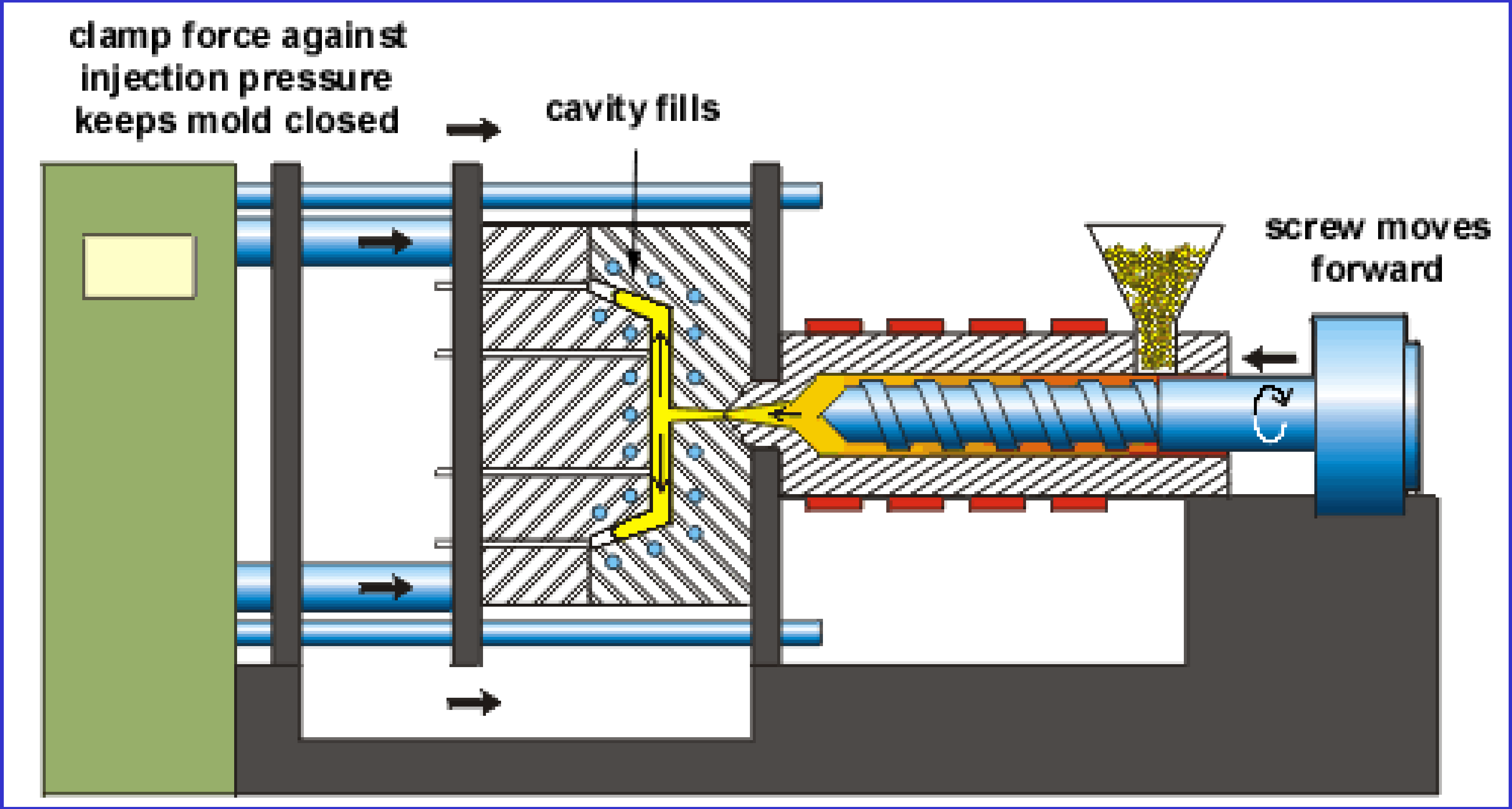
Injection Molding

1. Plasticizing the Resin



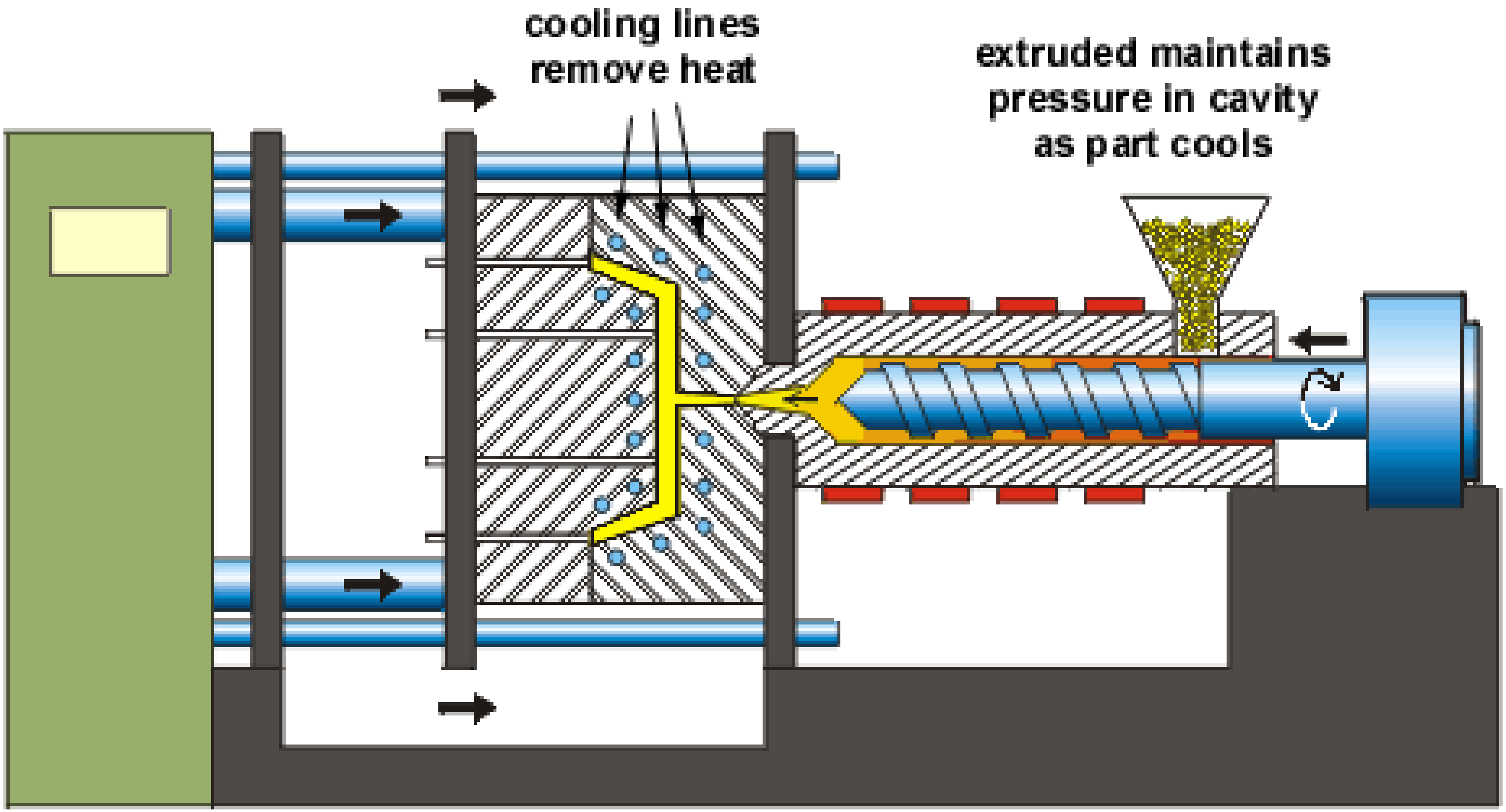
Injection Molding

2. Injecting the resin



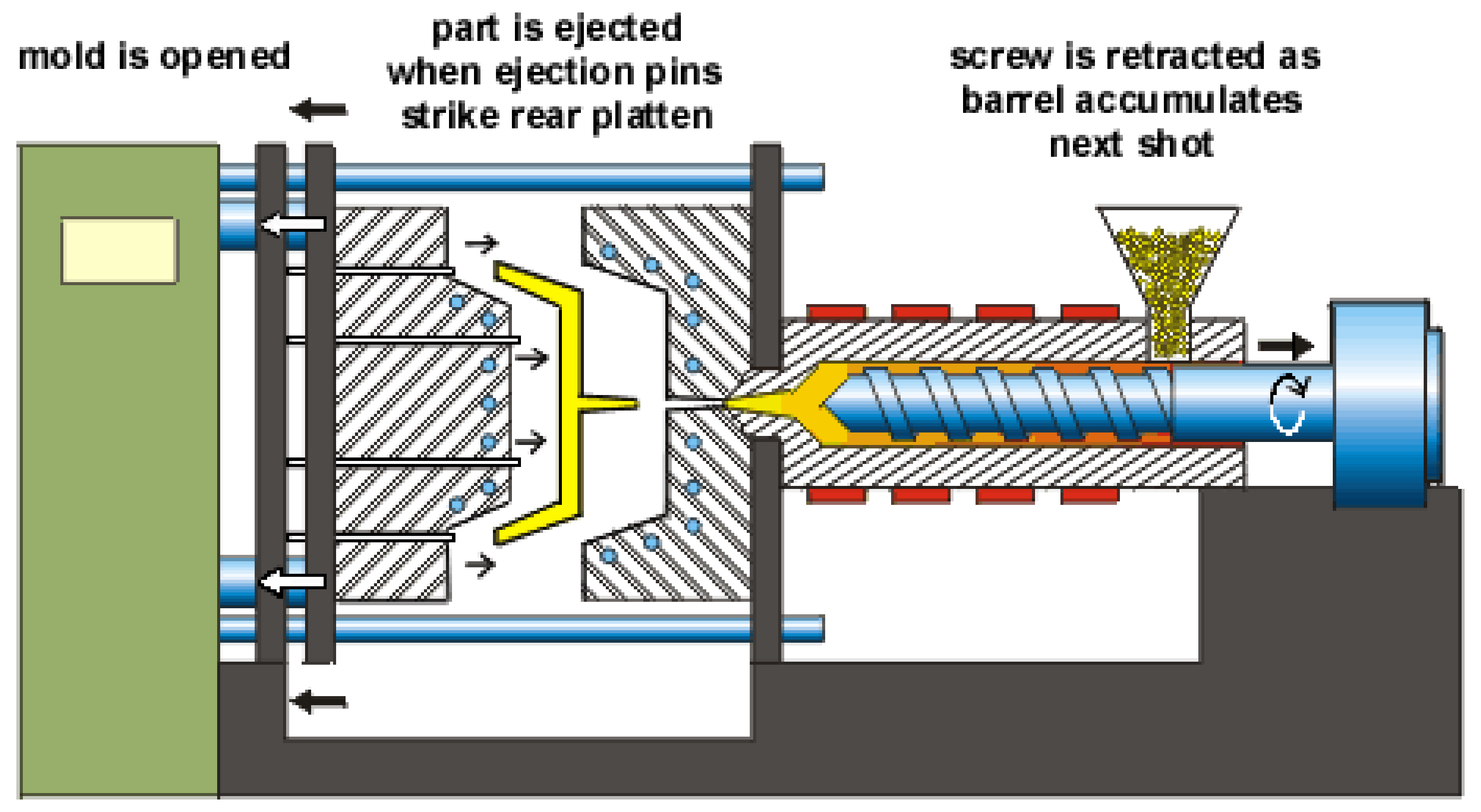
Injection Molding

3. Cooling the part



Injection Molding

4. Ejecting the part



Injection Molding

Injection Molding machine

Primary Forming Processes

Cost

- Dies and molds cost on the order of \$10,000 to \$100,000
- Inflexibility of tooling
- Economical when lot size is large (on the order of 1,000 parts or higher)
- Does not require highly skilled workers

Primary Forming Processes

Production Rate

- High Production Rates
- Lower cycle times (ranging from seconds to minutes)
- Setup times are on the order of eight (8) hours

Primary Forming Processes

Quality

- Can achieve surface finishes of 1μm to 2μm R_a
- Sand casting can produce parts with up to 25μm R_a
- Require secondary removal processes
- Porosity in cast
- Dimensional accuracy
- Quality influenced by process parameters

Primary Forming Processes

Flexibility

- Limited by kinematics of forming processes
- Only one part geometry can be produced for a die geometry
- Part geometry cannot be changed through workpiece-tool motions
- Can produce parts of intricate geometric features

Primary Forming Processes

Characteristics

Table 2.2

	Cost	Production Rate	Quality	Flexibility
Forming Process	High Tooling/ Low Labor Cost	High	Medium to low	Low

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Deforming Processes

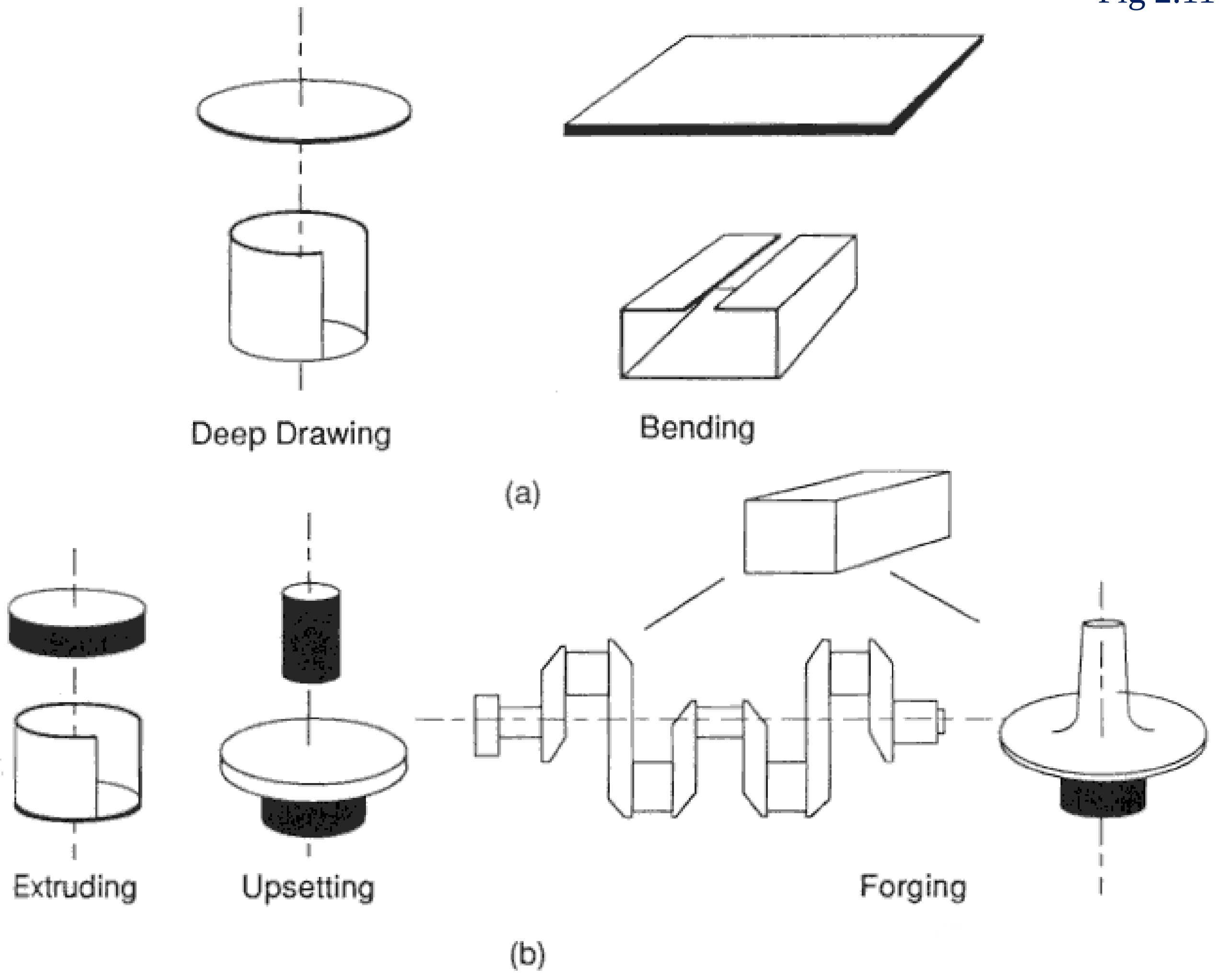
Criterion of temperature

- ***Hot forming*** processes
- ***Cold forming*** processes

Deforming Processes

Sheet (a) and Bulk (b) Deforming Techniques

Fig 2.11



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Deforming Processes

Criterion of stress

- ***Compressive forming-***plastic deformation of the solid body is achieved by uni- or multi-axial compressive loading
- ***Tensile forming-*** plastic deformation of the solid body is achieved through uni- or multi-axial tensile stresses
- ***Combined tensile and compressive forming-***plastic deformation of the solid body is achieved by combined both tensile and compressive loading

Deforming Processes

Criterion of stress (cont.)

- ***Bending-*** plastic deformation of the solid body is achieved by means of a bending load
- ***Forming by shearing-*** plastic deformation of the solid body is achieved through of a shearing load

Deforming Processes

Cost

- High tooling cost (up to $250,000 per die)
- Inflexibility of tooling
- High machinery cost (up to $200,000 per machine)
- Economical when lot size is large (several million parts)
- Does not require highly skilled workers

Deforming Processes

Production Rate

- High production rates (up to 5,000 parts per hour)
- Require large lot sizes
- Setup times are on the order of several hours
- Impractical for small lot size production

Deforming Processes

Quality

- Can achieve surface finishes down to 0.8μm R_a (extrusion, cold rolling)
- Hot forming can produce parts with up to 50μm R_a
- Require secondary finishing operations
- Produces work hardening in the workpiece
- Increases the mechanical strength of the part
- Risk for crack and overlap formation in the workpiece

Deforming Processes

Flexibility

- Limited by kinematics of deforming processes (due to motion, force or energy)
- Only one part geometry can be produced for a die geometry
- Part geometry cannot be changed through workpiece-tool motions
- Can produce parts of limited geometric features

Deforming Processes

Characteristics

Table 2.3

	Cost	Production Rate	Quality	Flexibility
Deforming Process	High Tooling/ Low Labor Cost	High	Medium to low	Low

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Removing Processes

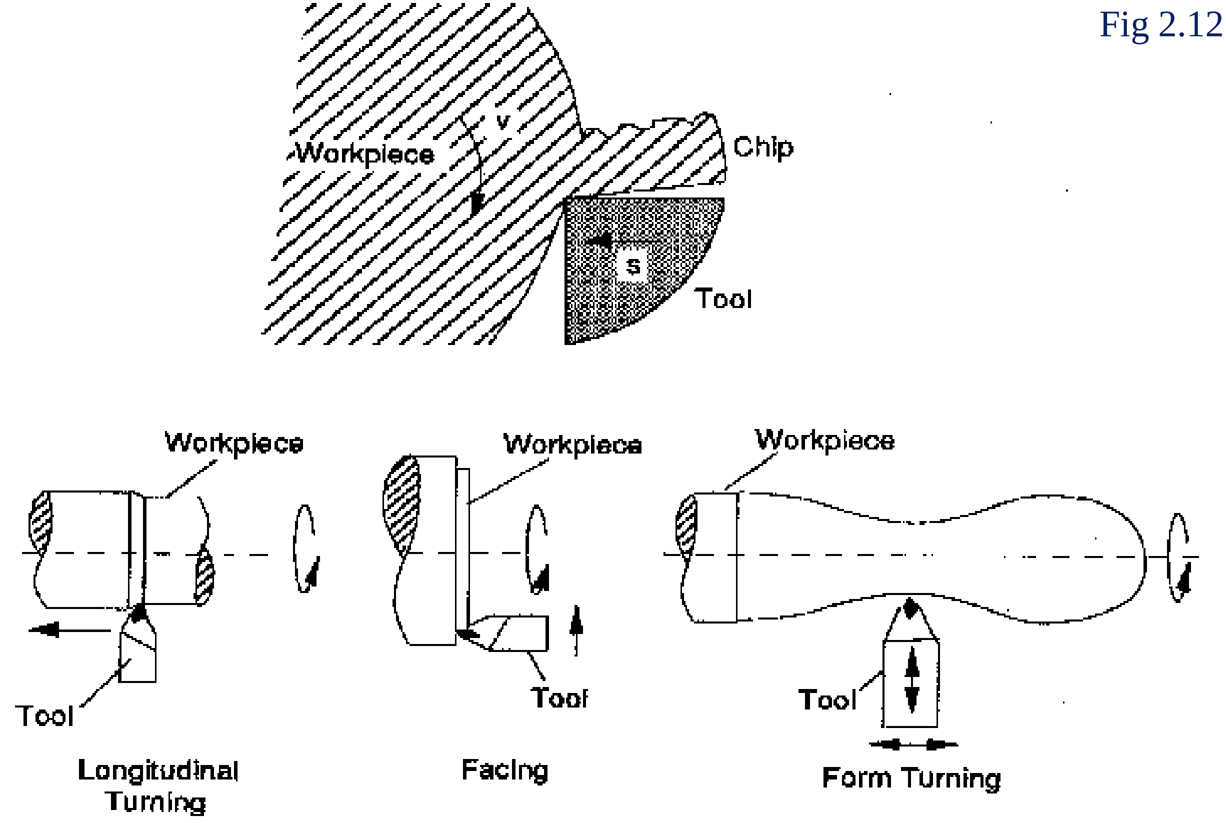
Material removal mechanisms

- ***Mechanical*-**the mechanical stresses induced by a tool overcome the strength of the material
- ***Thermal*-**thermal energy provided by a heat source melts and/or vaporizes the volume of the material to be removed
- ***Electrochemical*-** electrochemical reactions induced by an electrical field destroy the atomic bonds of the material to be removed
- ***Chemical*-** chemical reactions destroy the atomic bonds of the material to be removed

Removing Processes

Common Turning Processes

Fig 2.12



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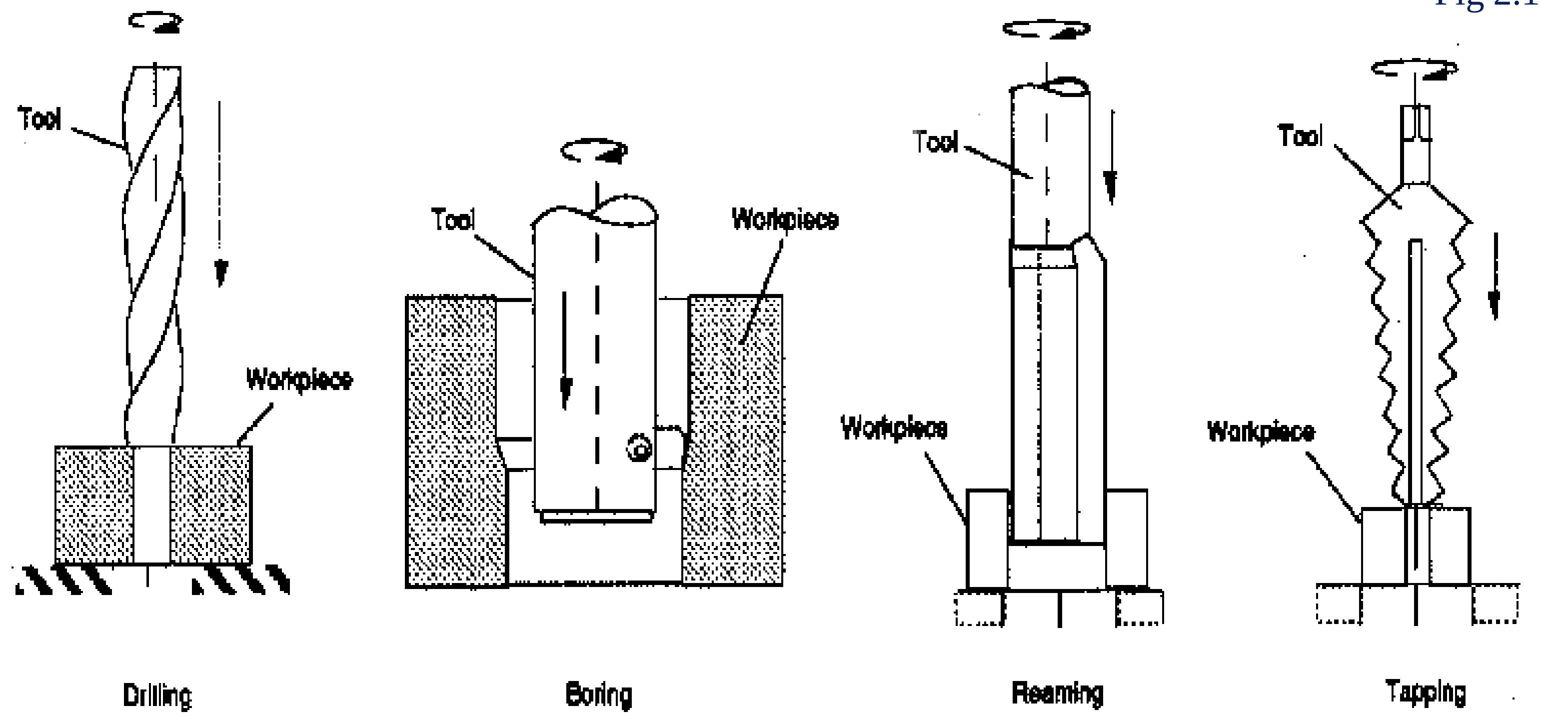
Removing Processes

Common Drilling Processes

Fig 2.14



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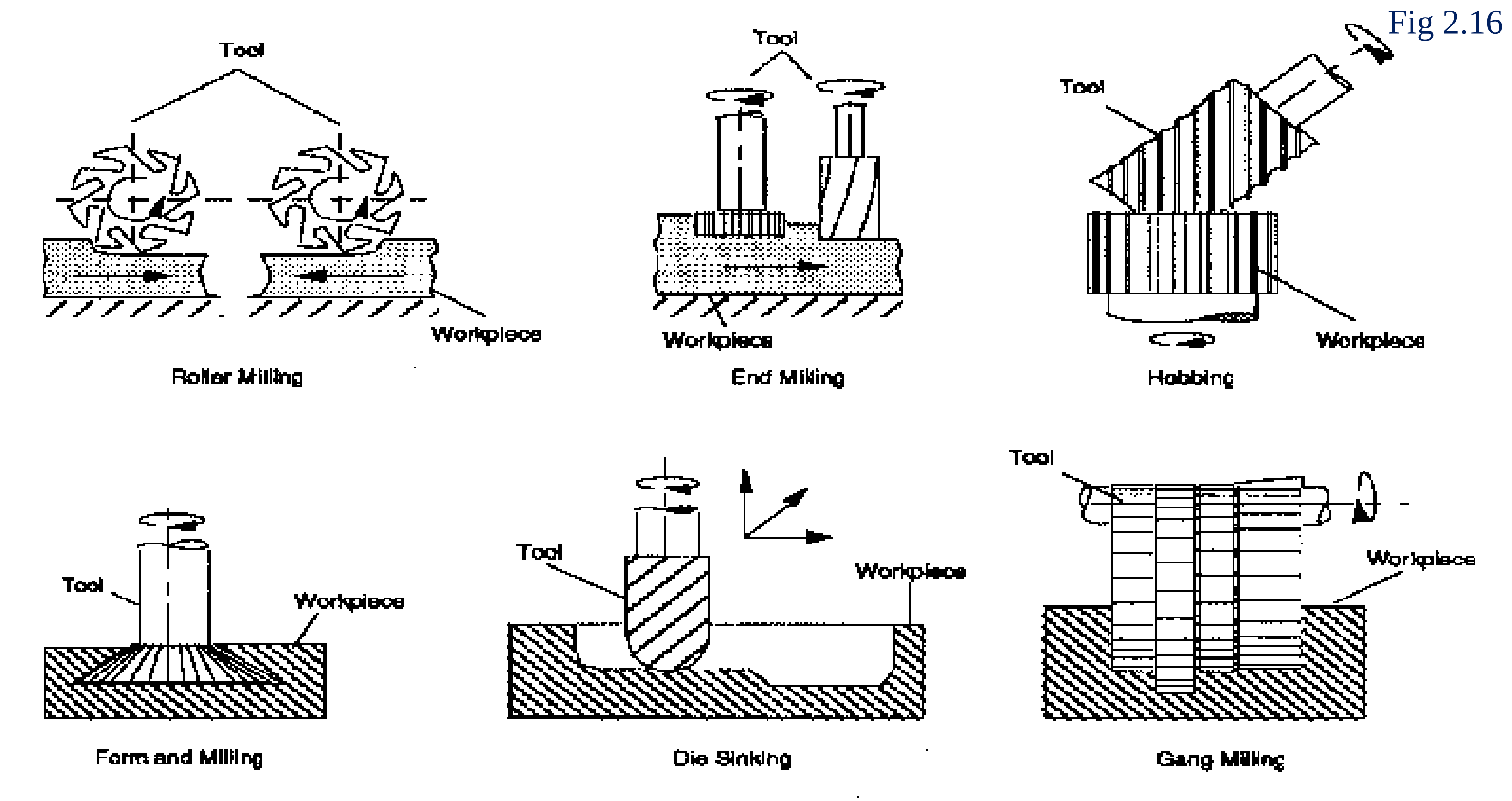
Removing Processes

Common Milling Processes

Fig 2.16



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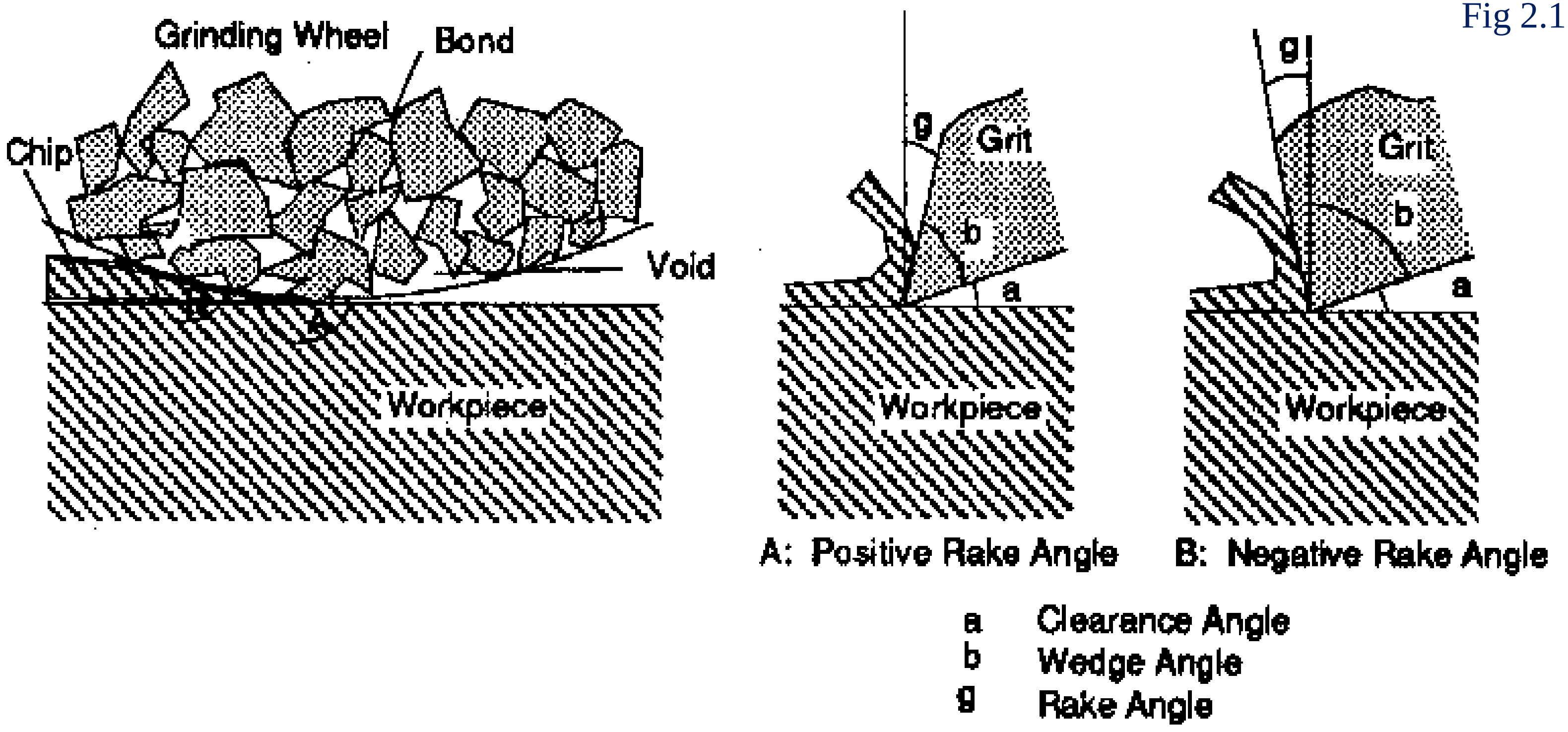
Removing Processes

Basic Mechanism of the Grinding Processes

Fig 2.17



A: Positive Rake Angle

B: Negative Rake Angle

a Clearance Angle
b Wedge Angle
g Rake Angle

Contact Between Workpiece and Grinding Wheel

Cutting Geometry for One Cutting Grit

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Removing Processes

Basic Grinding, Honing and Lapping Processes

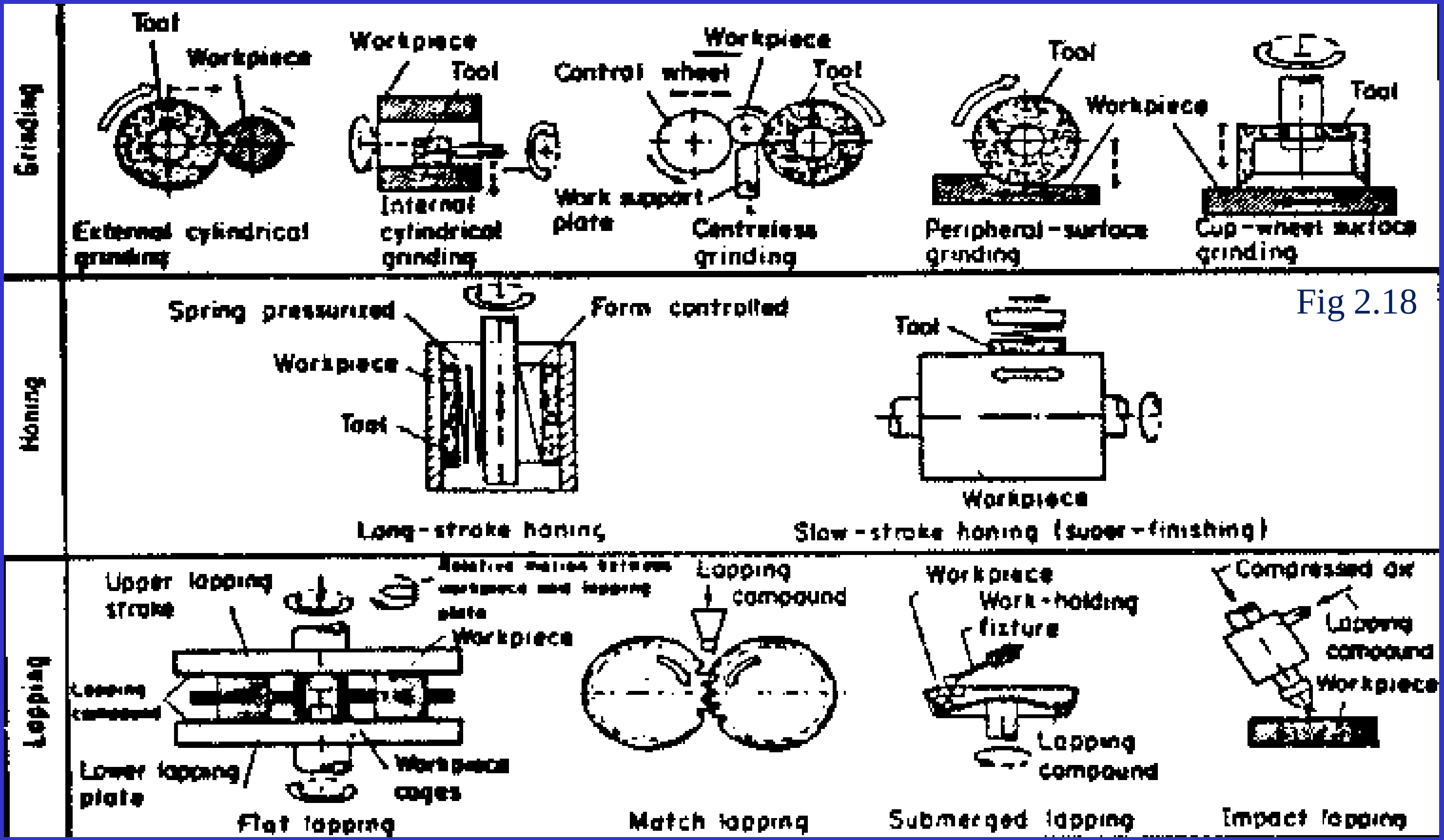

Fig 2.18

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Removing Processes

Basic Surface Grinding Techniques

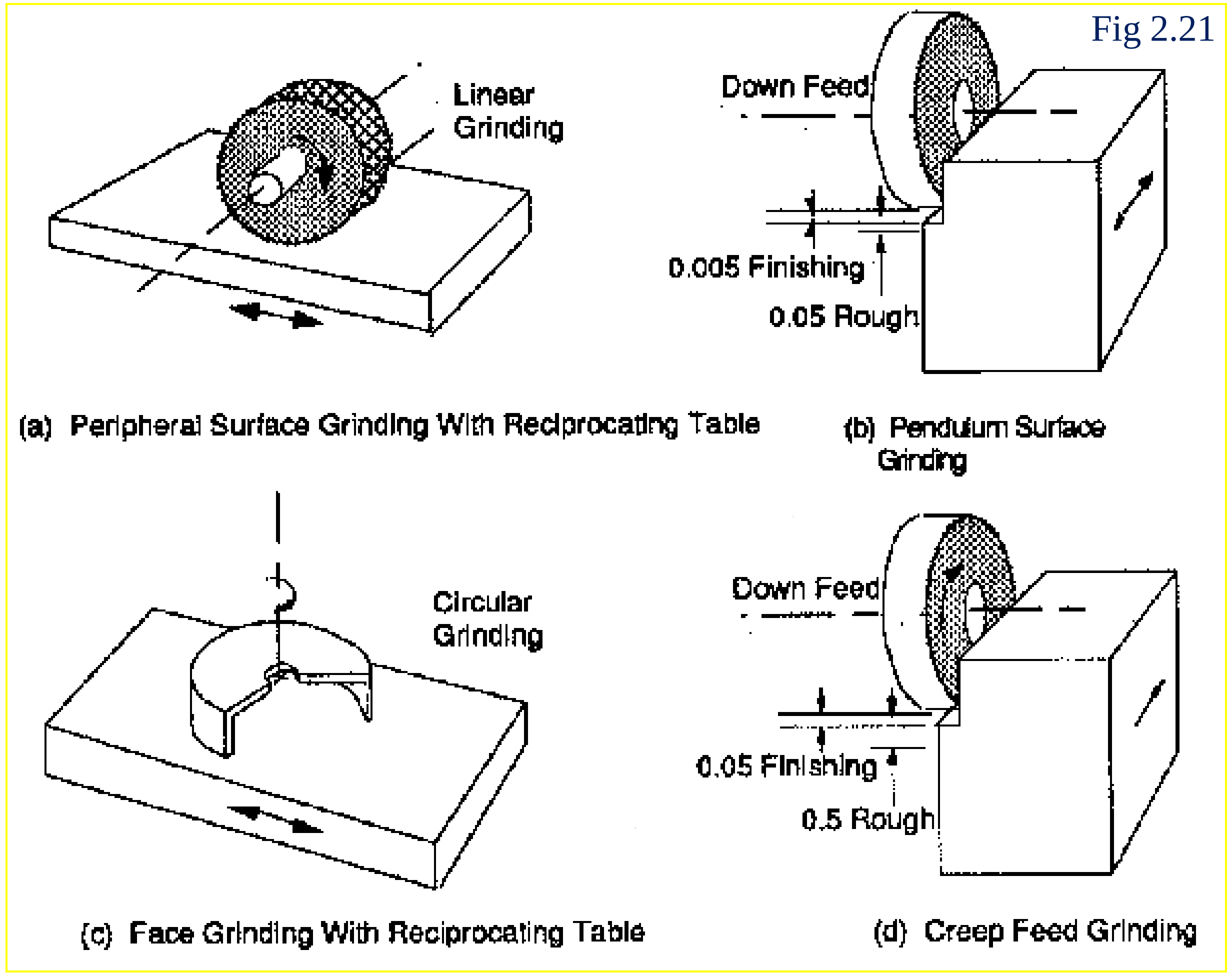

Fig 2.21

(a) Peripheral Surface Grinding With Reciprocating Table

(b) Pendulum Surface Grinding

(c) Face Grinding With Reciprocating Table

(d) Creep Feed Grinding

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Removing Processes

Cost

- Machines cost from $10,000 to $80,000 (CNC)
- Tooling cost ranges from $1 to $100
- Requires skilled labor for programming or manually setting workpiece and tool kinematics

Removing Processes

Production Rate

- Production rate is much lower than casting or deforming processes
- Material removal rate depends on surface quality required, workpiece material, tool material and cutting fluid
- Material removal rates for steel range from 1mm^3/min (grinding) to 10cm^3/min (milling)
- Setup times are on the order of several minutes to one hour

Removing Processes

Quality

- Processes based on thermal removal, like flame cutting, provide surface roughness up to 25µm R_a
- Processes based on mechanical removal, like grinding, provide surface roughness of the order of 0,05µm R_a
- Better surface quality achieved through parameter adjusting, e.g. feed rate/tooth or feed rate/revolution

Removing Processes

Flexibility

- Geometry of the part is defined by the geometry and kinematics of tool and workpiece
- Wide range regarding size, shape, and surface quality for the parts produced

Removing Processes

Characteristics

Table 2.5

	Cost	**Production Rate**	**Quality**	**Flexibility**
Removing Process	High Tooling/ Low Labor Cost	Medium (Milling) to Low (Grinding)	High	High

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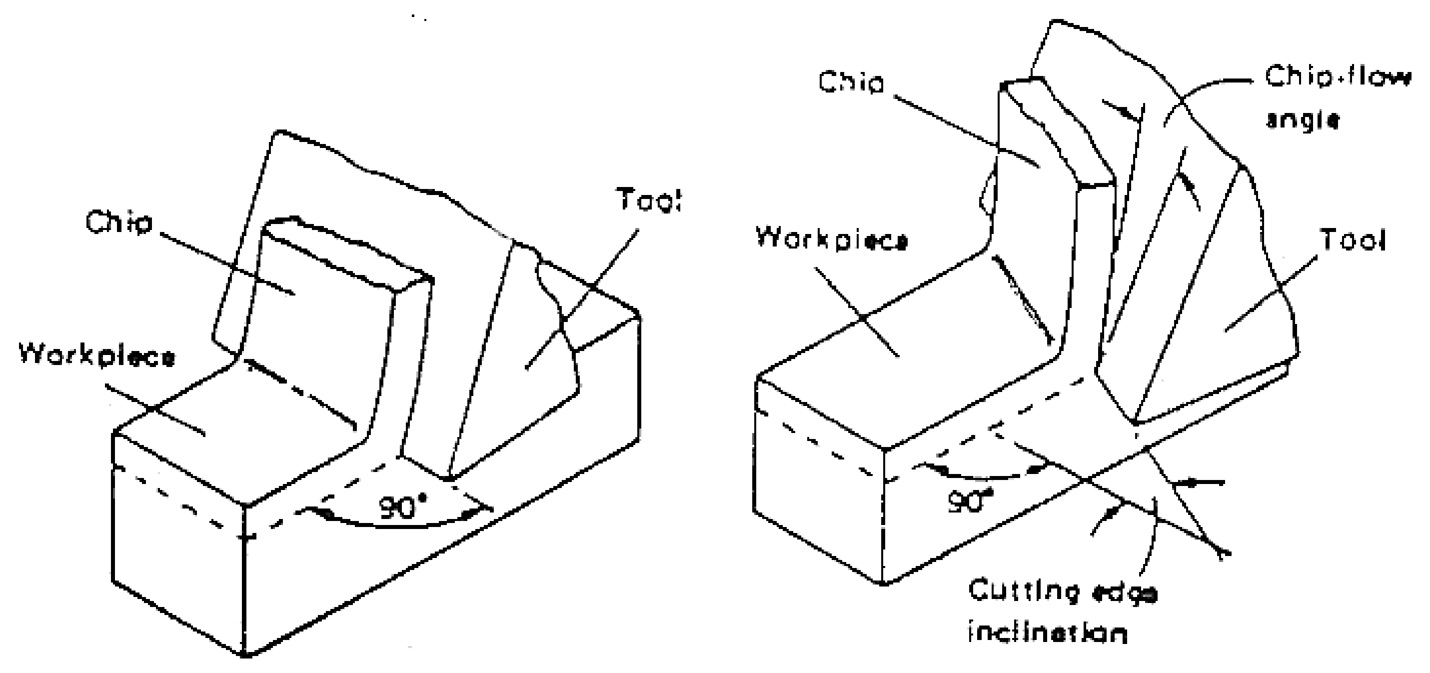
Orthogonal Cutting

Process Model

- *Goals*
  - Optimization
  - Control
- *Assumptions*
- *Empirical—Theoretical Approach*

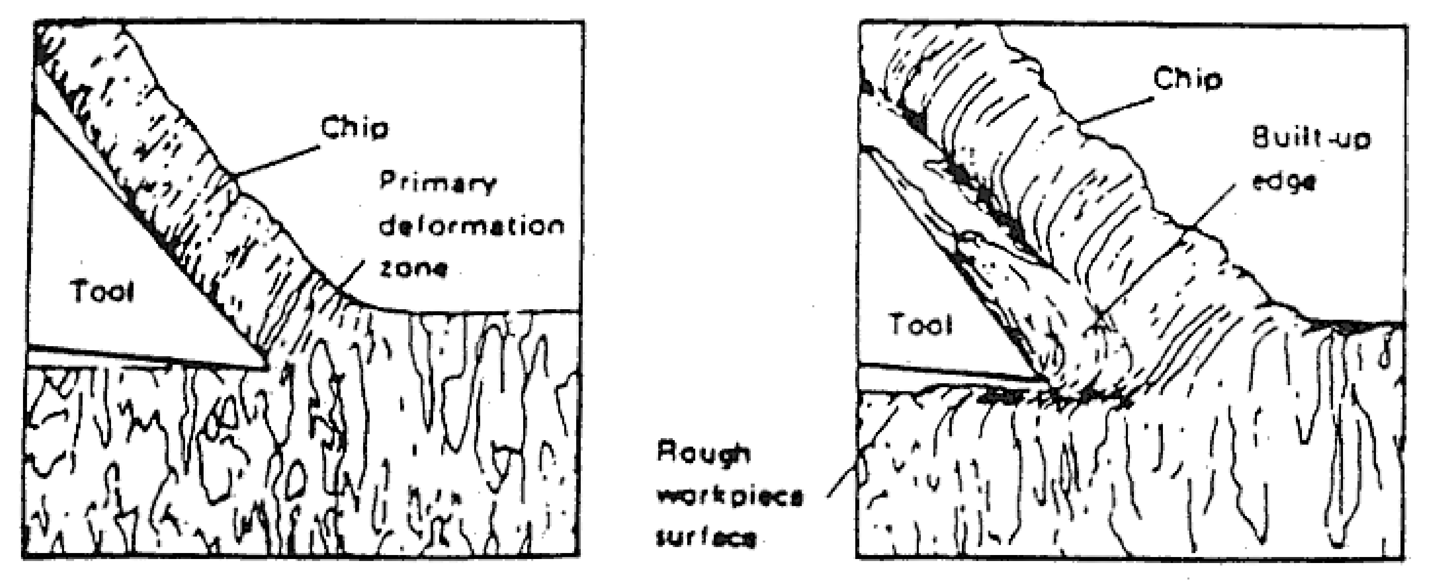
Orthogonal Cutting

Process Model (assumed chip formation)



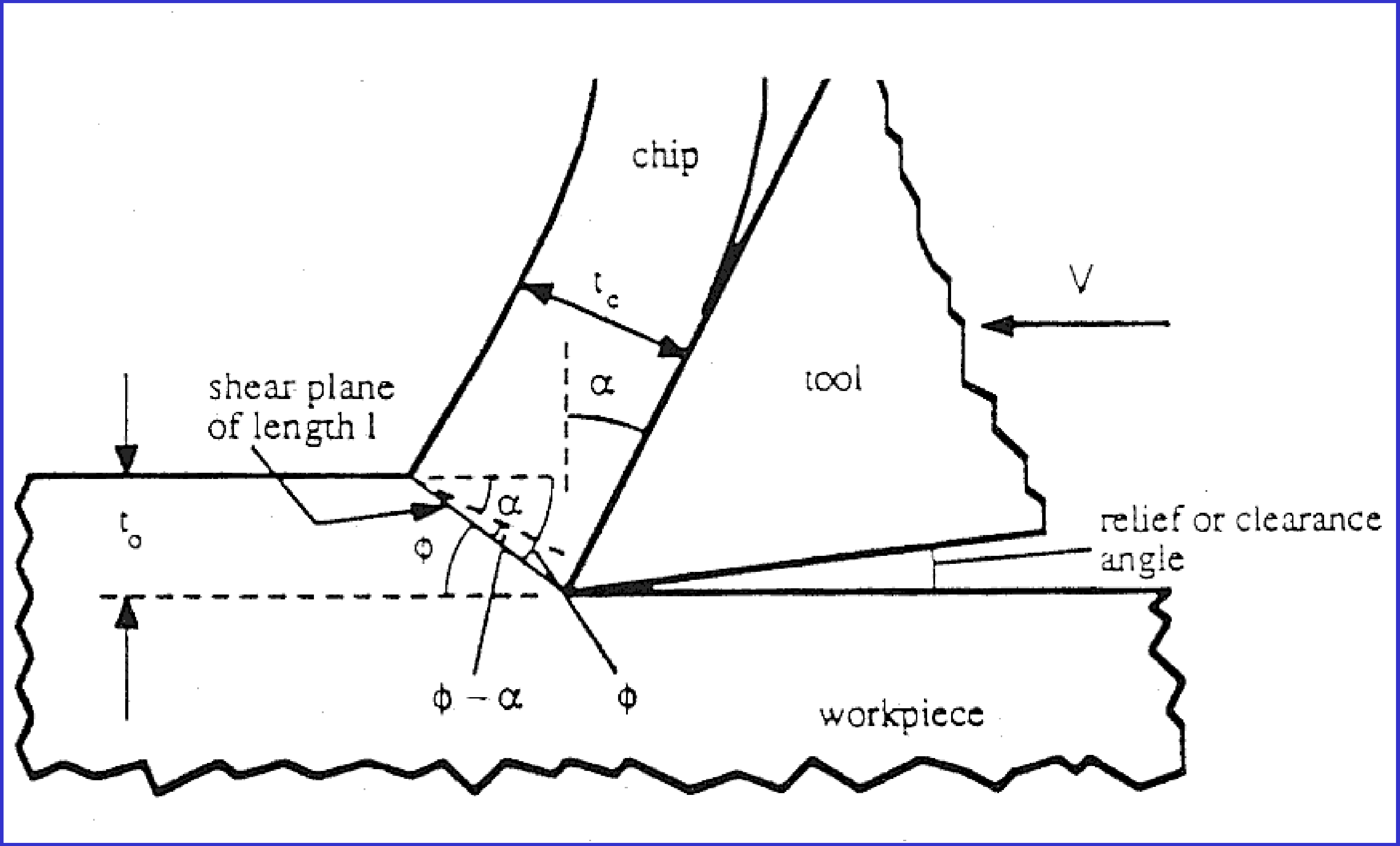
Orthogonal Cutting

Real chip formation



Orthogonal Cutting

Process Model: The Shear Plane Assumption



Orthogonal Cutting

The Shear Plane Assumption: Relations

l , length on shear plane : $l_{shear\ plane} = \dfrac{t_0}{\sin\varphi} = \dfrac{t_C}{\cos(\varphi - \alpha)}$

φ , shear angle t_C , chip thickness after cutting

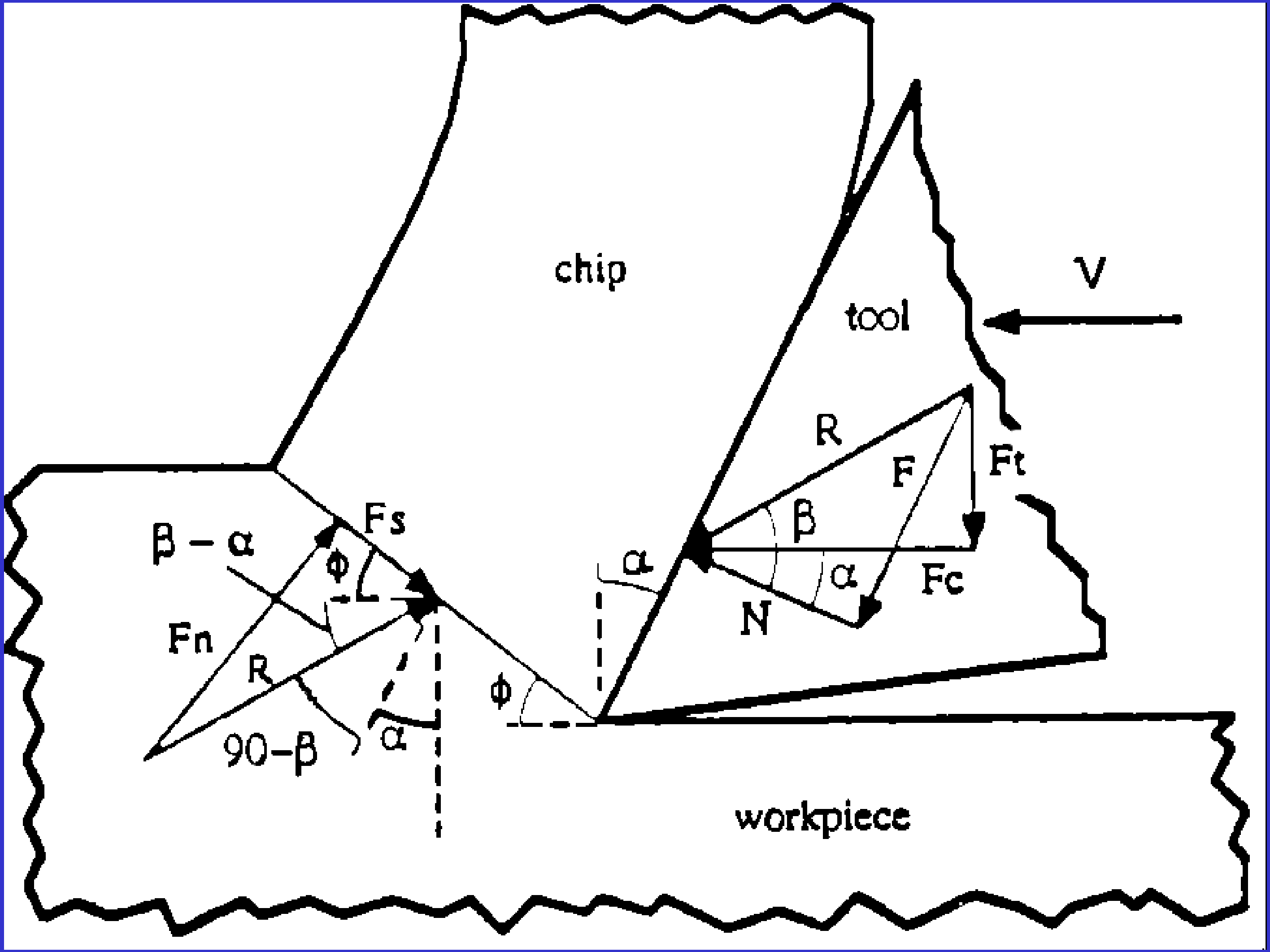
t_0 , chip thickness before cutting r , compression ratio

$$\frac{\sin\varphi}{\cos(\varphi-\alpha)} = \frac{t_0}{t_C} = r\,, \quad \frac{\sin\varphi}{\cos\varphi\cos\alpha + \sin\varphi\sin\alpha} = r\,, \quad \frac{\tan\varphi}{\cos\alpha + \tan\varphi\sin\alpha} = r$$

$$\tan\varphi = r\cos\alpha + r\tan\varphi\sin\alpha\,, \qquad \tan\varphi = \frac{r\cos\alpha}{1 - r\sin a}$$

Orthogonal Cutting

Process Model: The Rigid Body Assumption (chip)



Orthogonal Cutting

The Rigid Body Assumption (chip) **: Relations**

R , resultant of cutting tool forces

F_t , normal to the cutting speed component

N , normal to the tool face component

F_n , normal to the shear plane component

F_C , cutting component

F , friction component

F_S , shear component

β, angle of friction

$$\boxed{\tan\beta = \frac{F}{N} = \mu}$$

Orthogonal Cutting

Minimization of the work for cutting

The cutting angle optimization

Work for cutting proportional to F_C , the cutting component

$$F_C = R\cos(\beta - \alpha),$$

$$R = \frac{F_S}{\cos(\varphi + (\beta - \alpha))}, \Rightarrow \qquad \boxed{F_C = \frac{\tau_S A_S}{\cos(\varphi + (\beta - \alpha))}\cos(\beta - \alpha)}$$

$$F_S = \tau_S A_S ,$$

$$A_S = \frac{A_C}{\sin\varphi}$$

Orthogonal Cutting

Minimization of the work for cutting

The shear angle optimisation

A_S , shear area

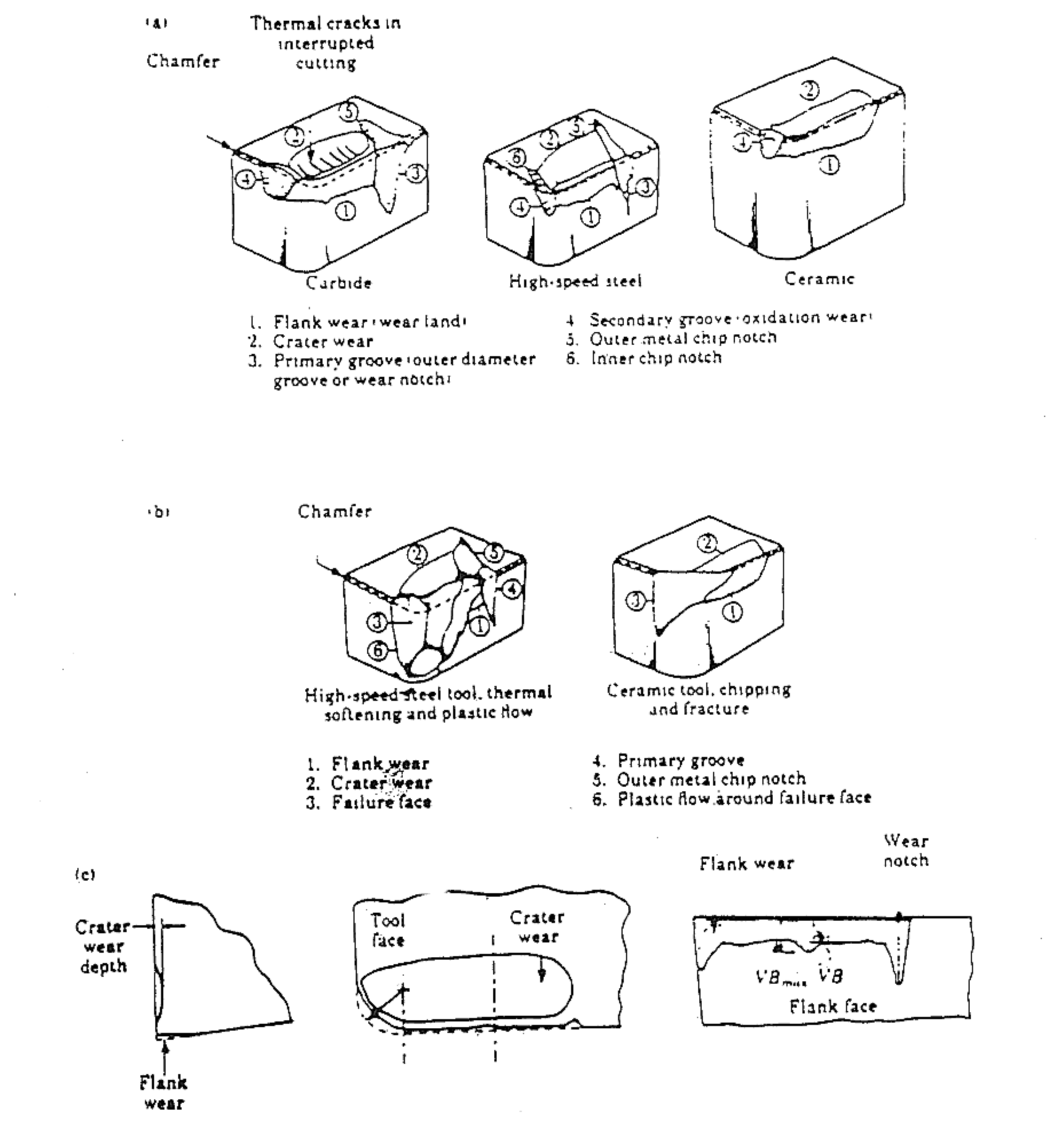
A_C , chip area before cutting

τ_S , shear stress component

Differentiating the resultant Equation for F_C with respect to φ, and equating to zero we get :

$$\boxed{2\varphi + \beta - \alpha = \frac{\pi}{2}}$$

Tool Wear



1. Flank wear (wear land)
2. Crater wear
3. Primary groove (outer diameter groove or wear notch)
4. Secondary groove (oxidation wear)
5. Outer metal chip notch
6. Inner chip notch

High-speed steel tool, thermal softening and plastic flow

Ceramic tool, chipping and fracture

1. Flank wear
2. Crater wear
3. Failure face
4. Primary groove
5. Outer metal chip notch
6. Plastic flow around failure face

Wear Behaviour of Cutting Tools

Important for

- *Cost*
- Quality
- Time
- Tool change
- Cutting speeds
- Damage on workpiece and machine

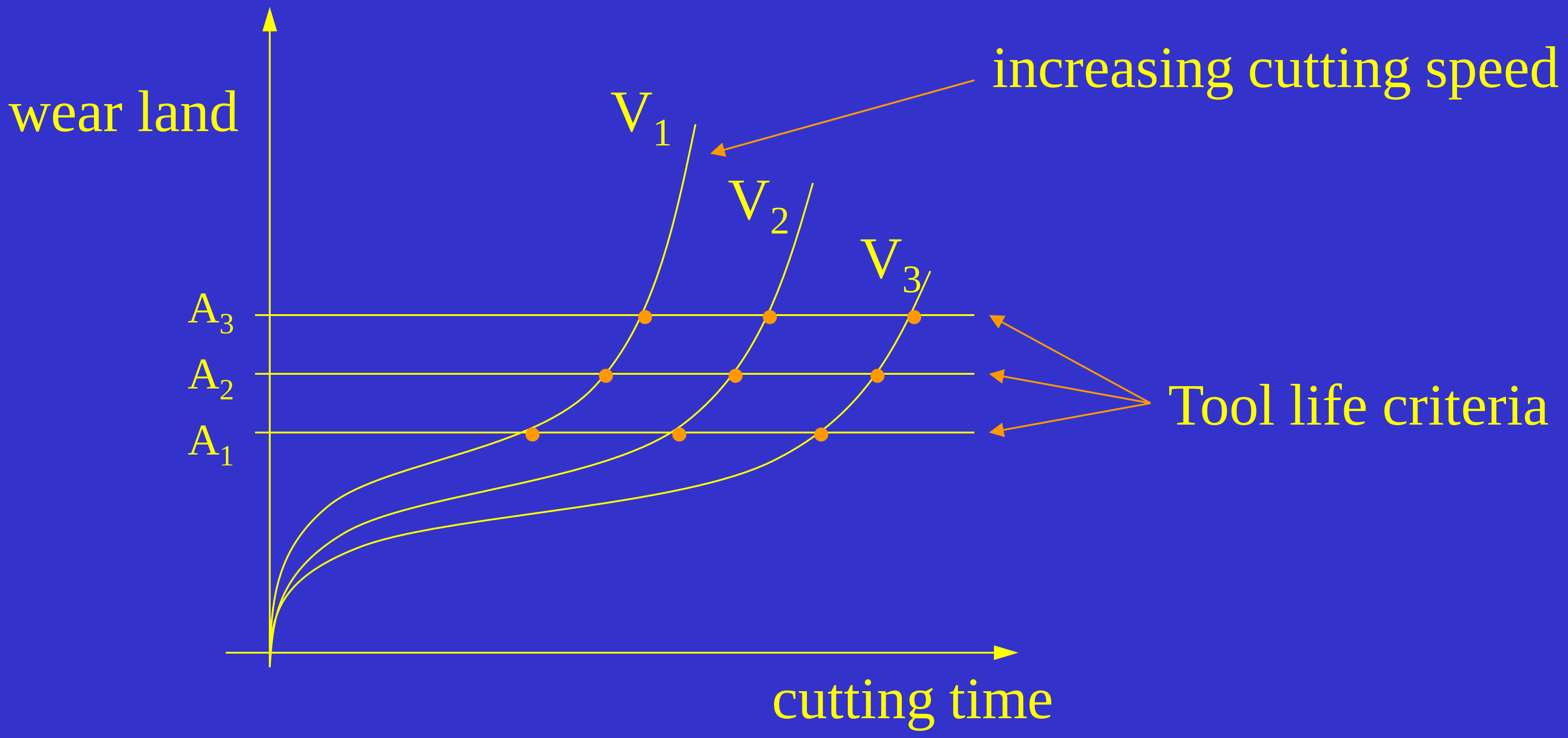
Wear Behaviour of Cutting Tools

Tool failure occurs due to

- Microchipping
- Gross Fracture
- Plastic Deformation

Wear Behaviour of Cutting Tools

Tool life criteria



Wear Behaviour of Cutting Tools

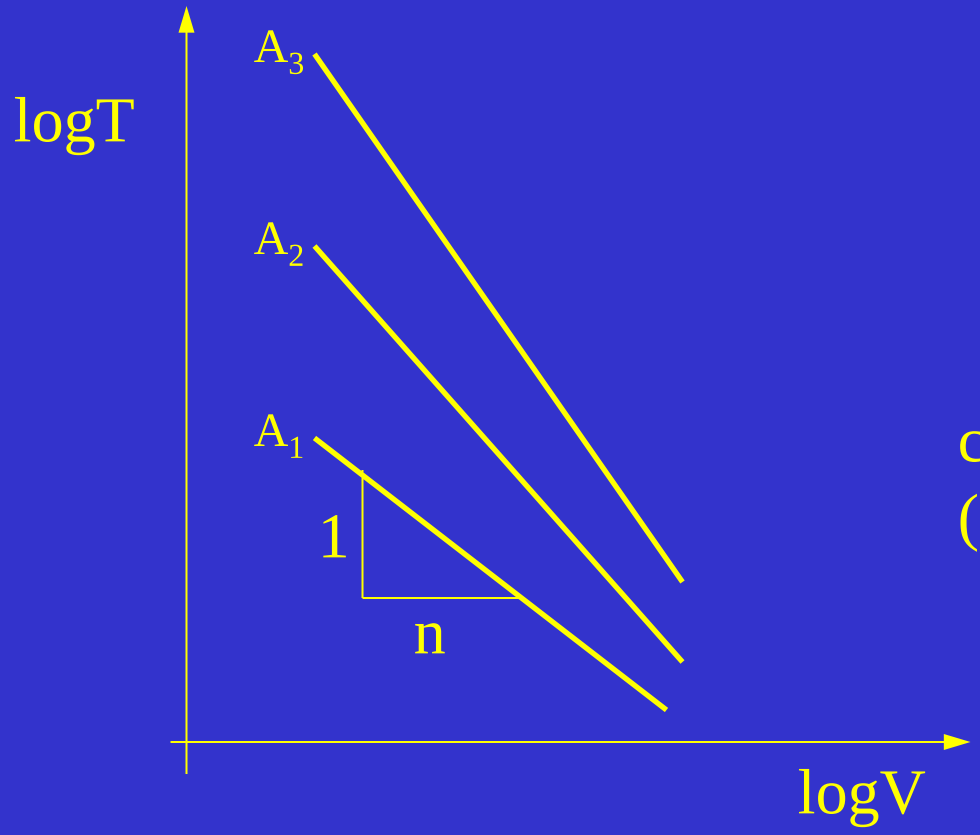
Tool life criteria

- Wear land
- Crater depth

⇒ Determined by Quality, Safety etc.

Wear Behaviour of Cutting Tools

Taylor's Equation



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

c: cutting speed giving one (1) minute tool life

Wear Behaviour of Cutting Tools

Generalised Taylor's Equation

Including:

- depth of cut
- feed

$$\boxed{TV^{1/n}t^{1/m}b^{1/\ell} = c'}$$

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European Union
European Social Fund

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