Lateness Policies

Part submissions
1 – 7 days late: 30% deduction
7 – 14 days late: 60% deduction
>14 days: 0%

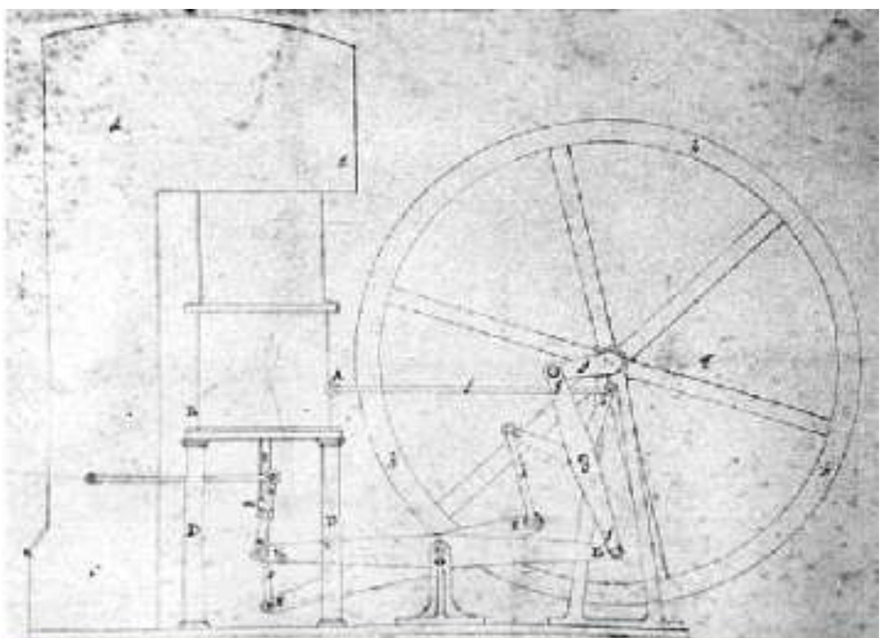
Lecture assignment submissions
Up to 24 hours late: 25% deduction
24 – 48 hours late: 50% deduction
>48 hours late: 75% deduction

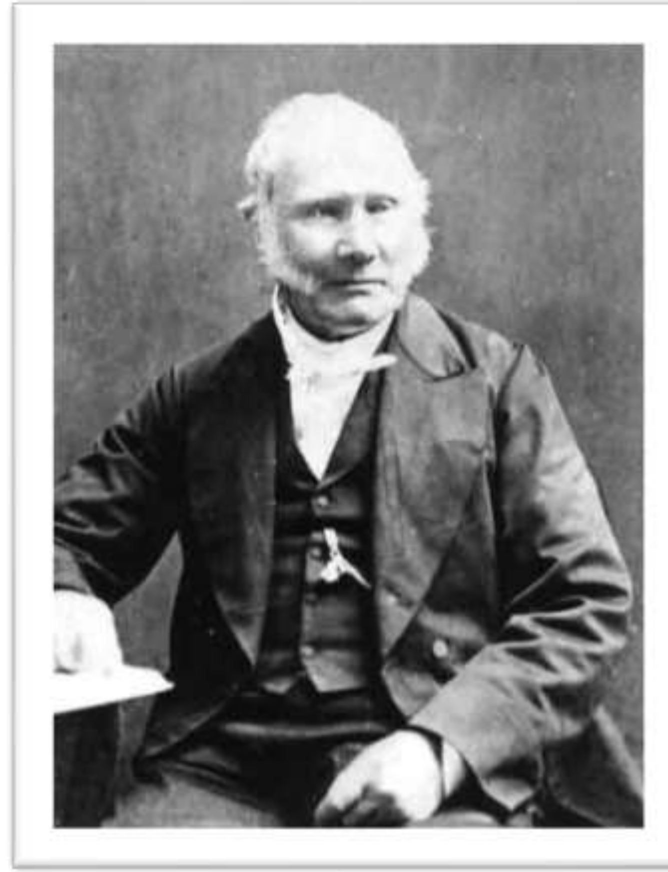
Lab quizzes
50% deduction for submission <u>after</u> your lab

The Stirling Engine

History

- Patented in 1816
- Closed-cycle regenerative hot air engine
- Theoretical full Carnot efficiency
- Any heat source
- Semi-reversible

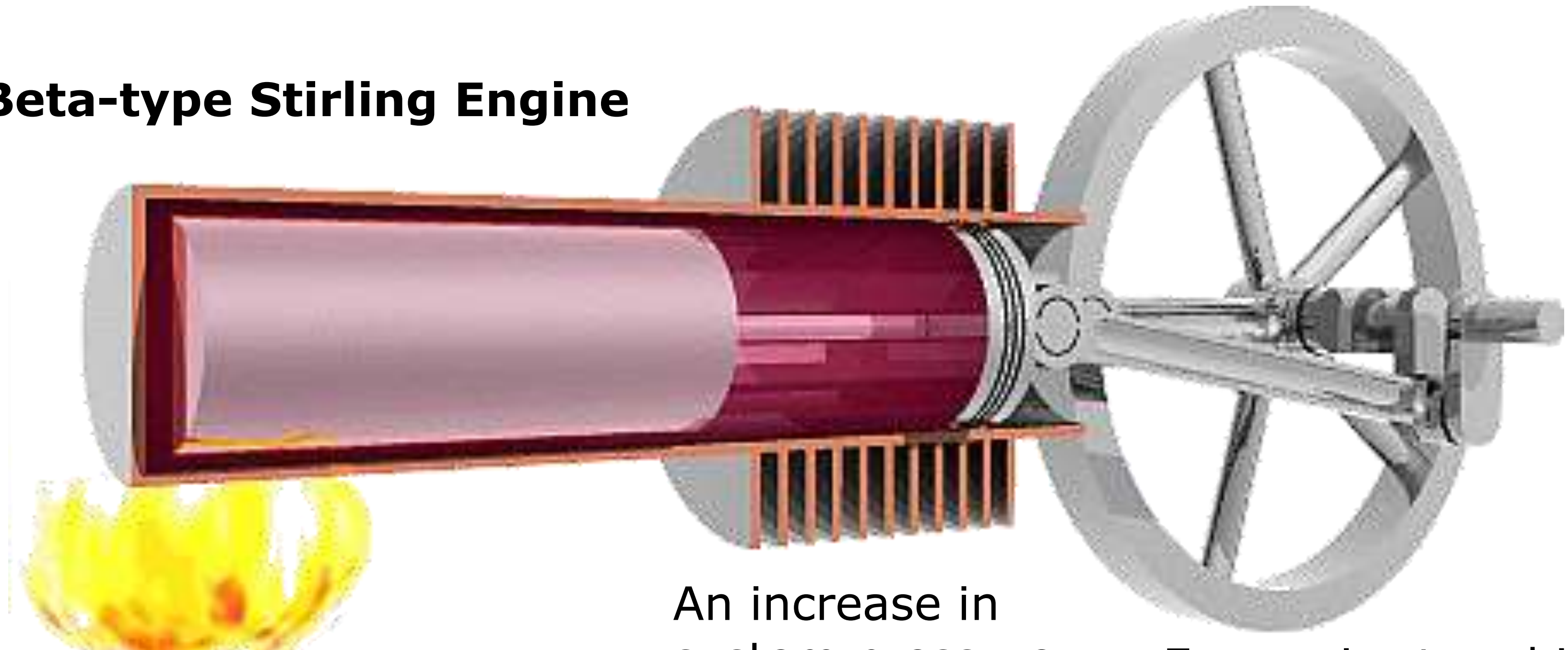




Dr. Robert L. Stirling

Operating Principles

Beta-type Stirling Engine



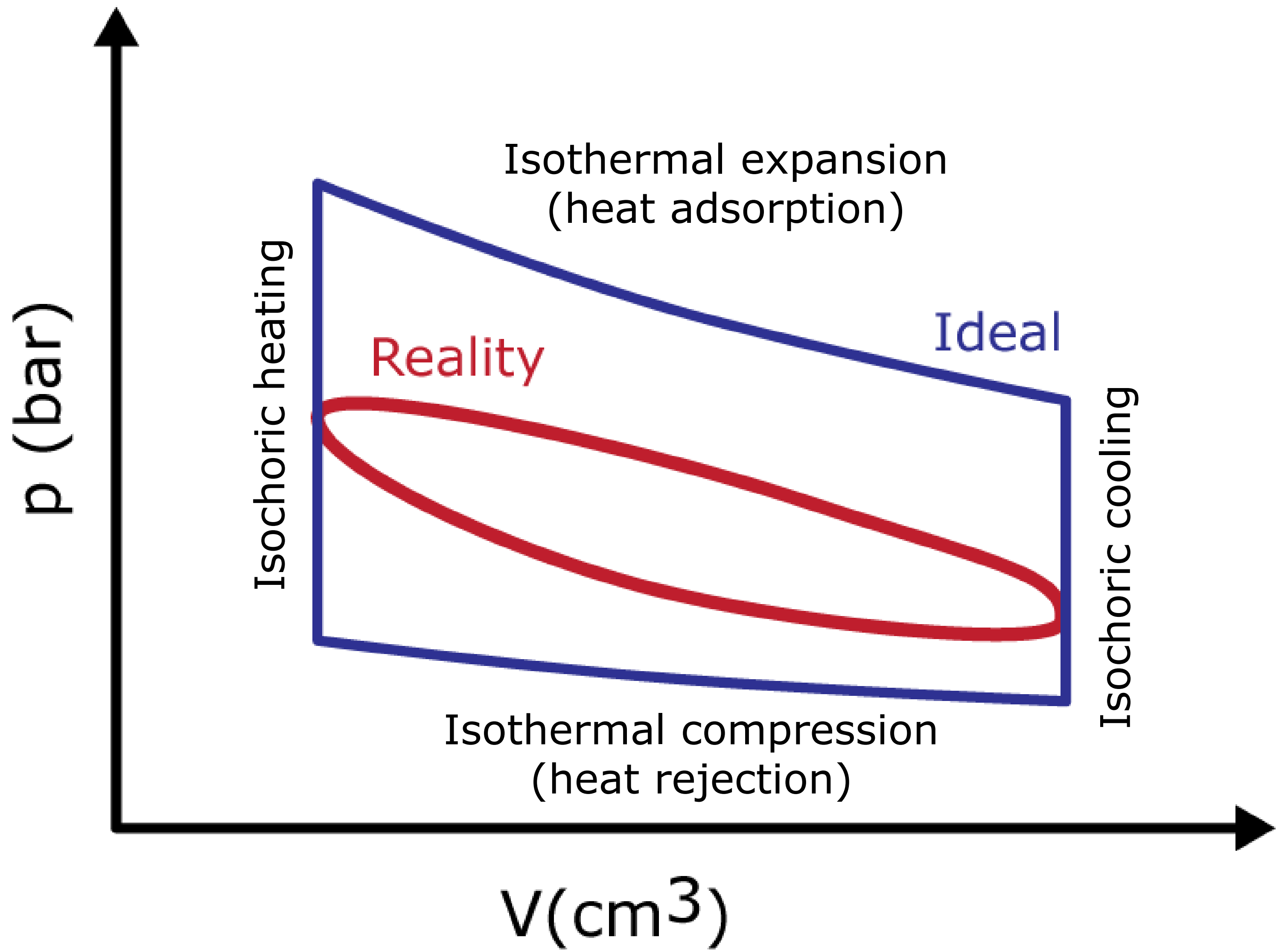
Heating the air chamber leads to an expansion of the working fluid
PV = nRT

An increase in system pressure drives the piston forward

Energy is stored in the flywheel to ensure full return of piston and smooth operation

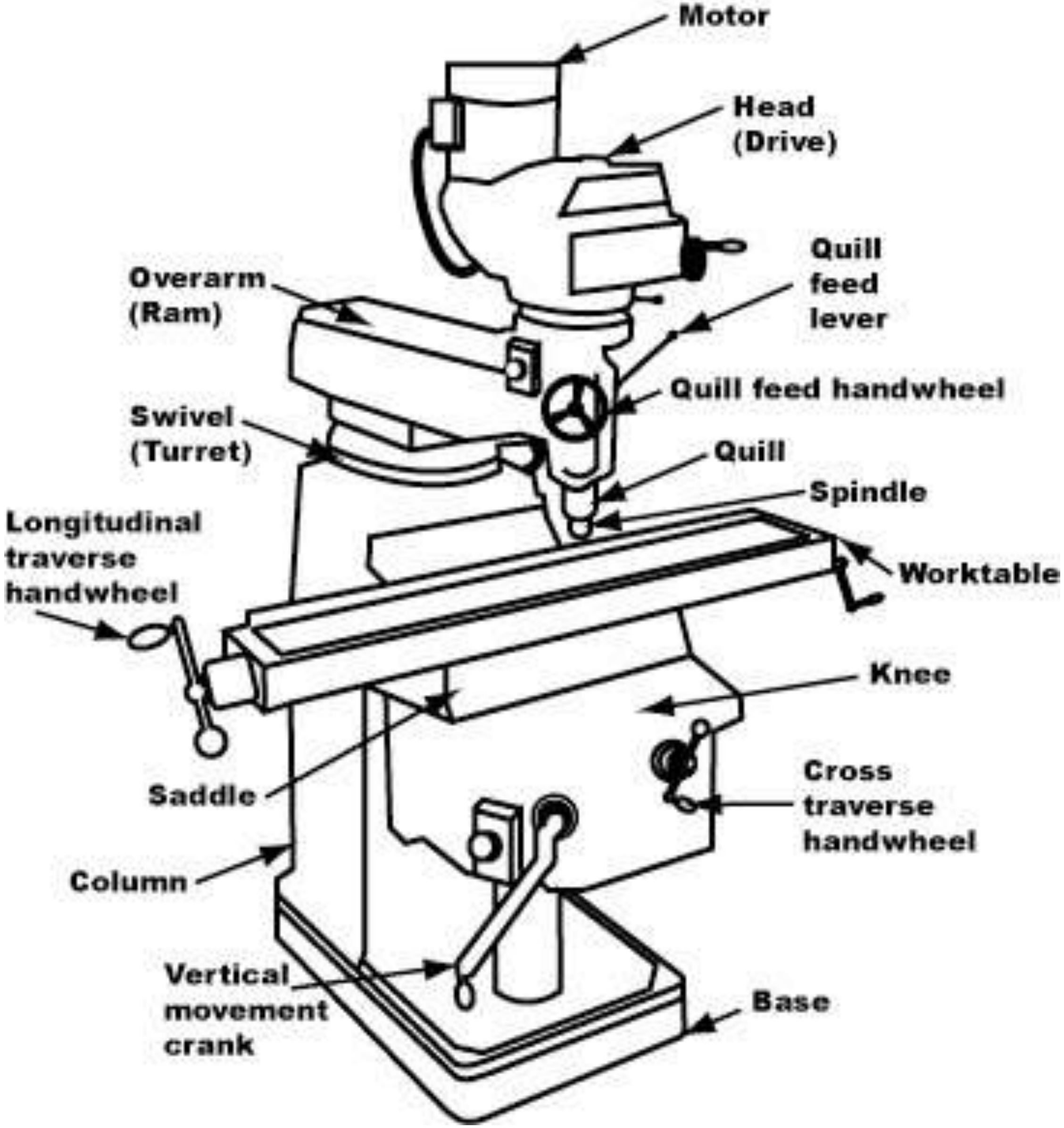
http://en.wikipedia.org/wiki/Stirling_engine

Operating Principles

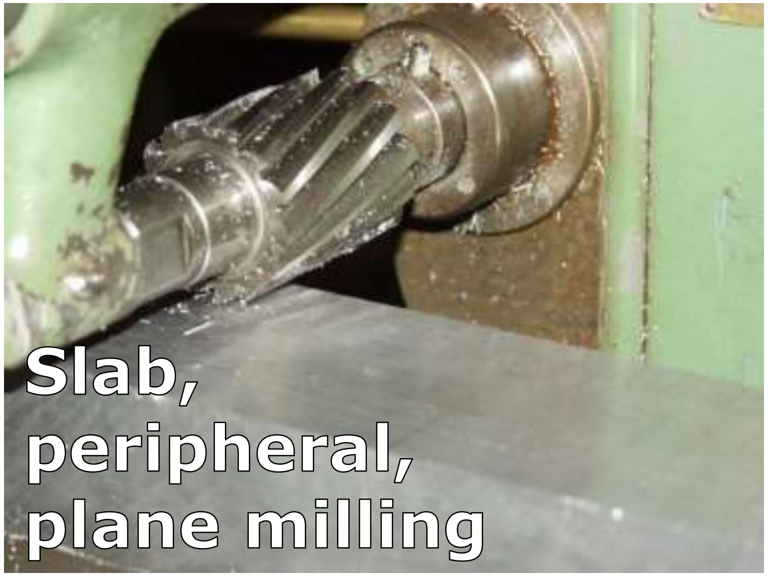



The Mill

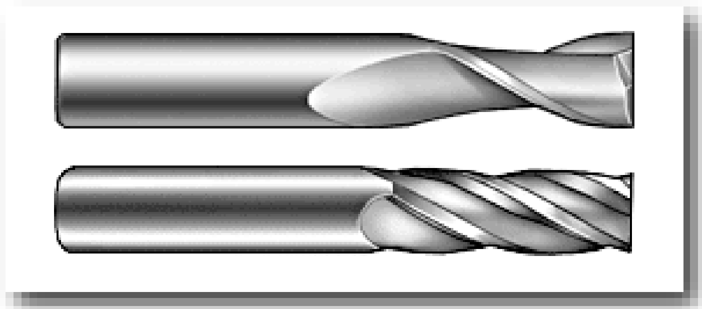
Anatomy of a Vertical Mill



Types of Milling

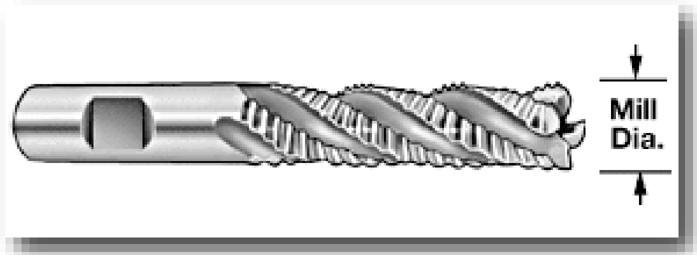


End Mills



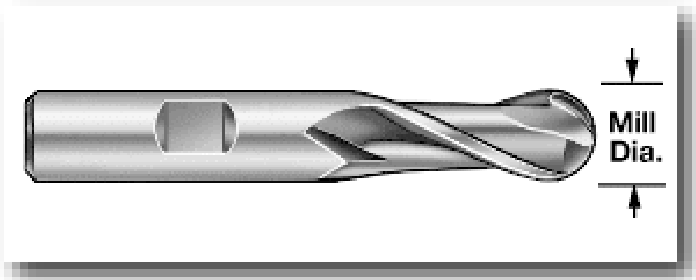
Square end

(pocket machining, end milling, profile milling)



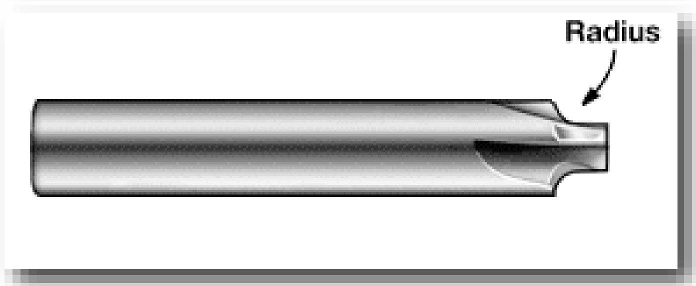
Roughing

(large volume material removal)



Ball end

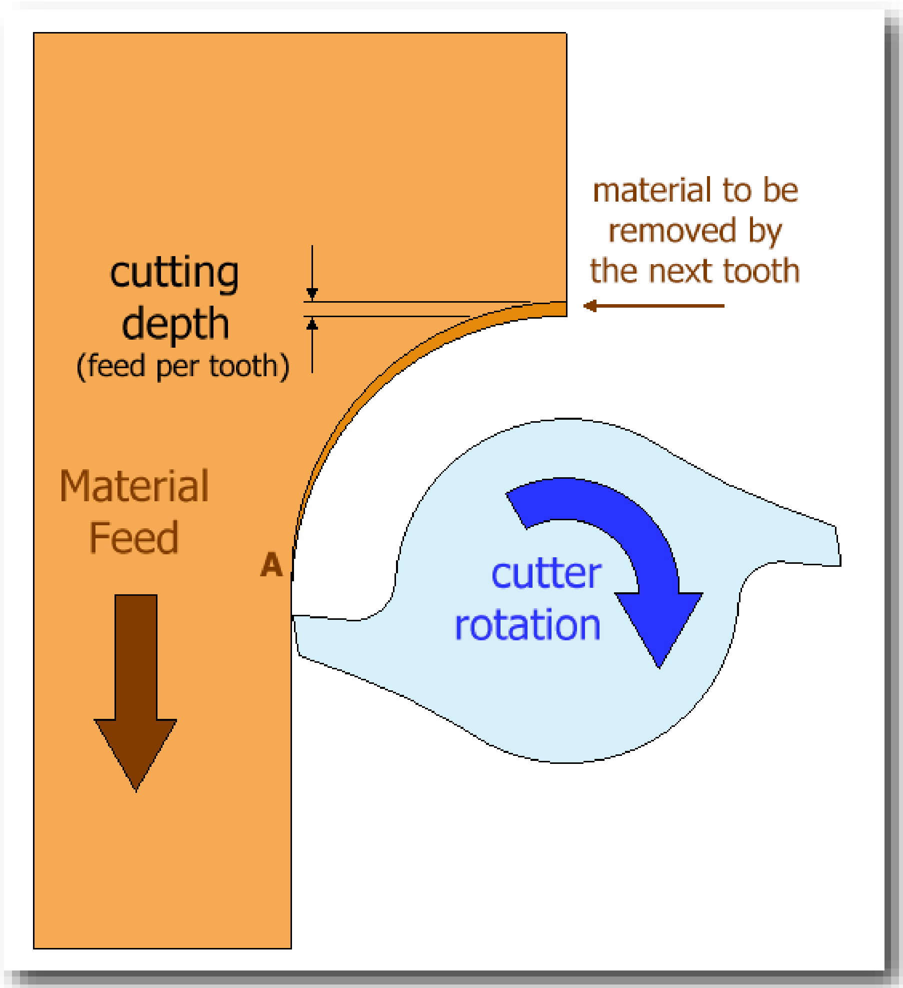
(shaping)



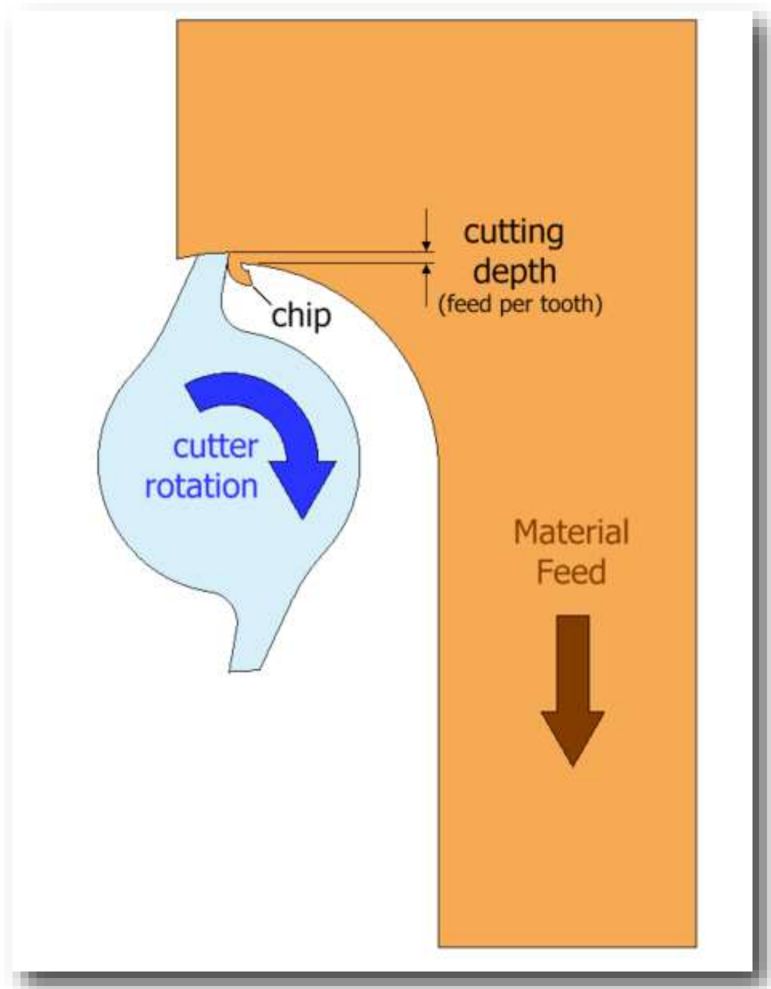
Corner rounding

(shaping – radii)

Types of Milling



Conventional (chip)



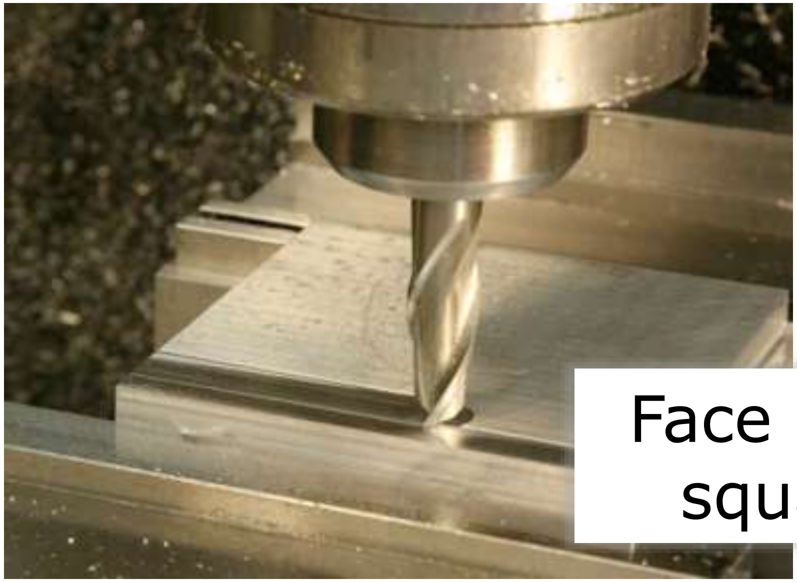
Climb

Face Milling Tools

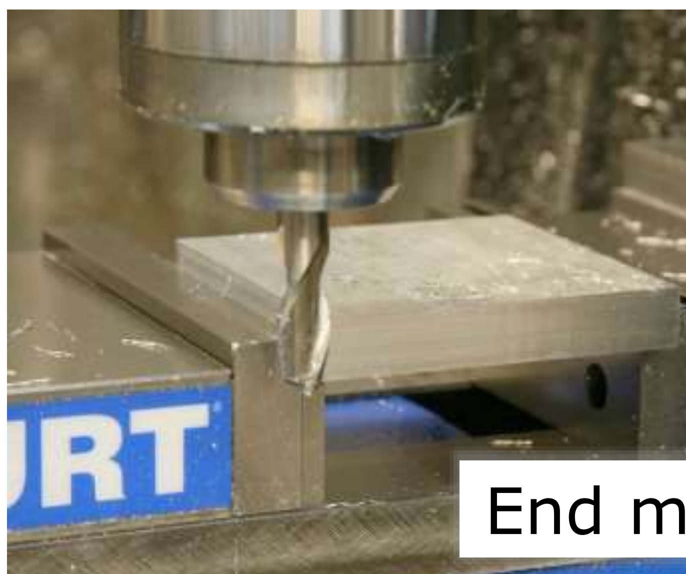
Fly Cutter
(single cutting edge, low throughput, cheaper)

Face Mill
(multiple edges / carbide inserts, higher throughput / feed rate, more expensive)

Milling Techniques



Face milling with a square end mill



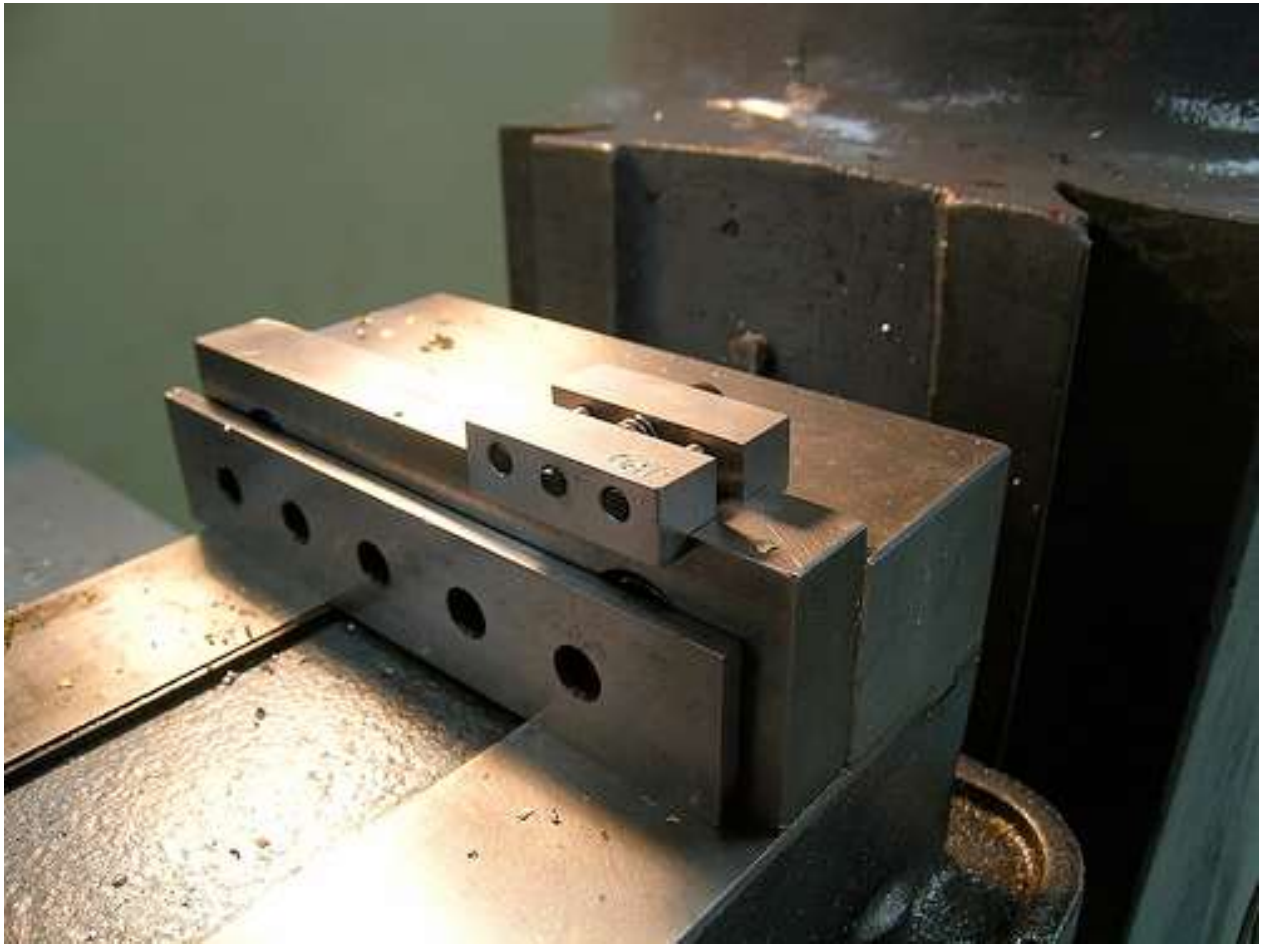
End milling

Work Holding (Vise)

Work Holding (Parallels)

Work Holding (Parallels)

Work Holding (Vise Stop)



Accurate placement along the lateral axis of the mill

Feeds and Speeds

Feeds and speeds determine the efficacy of the cutting operation and are heavily influenced by the type of cutting operation, materials being cut, and the cutting bit.

Speed Equation

You set this

Empirically determined parameter

$$\text{Spindle Speed[RPM]} = \frac{4 \text{ x Cutting Speed [SFPM]}}{\text{Tool Diameter [in.]}}$$

Provided or selected

Feeds and Speeds (Speed Derivation)

$$v = r\omega_r$$

Relationship between velocity and angular speed

$$\omega_{r[\mathrm{rad/min}]} = 2\pi\omega_{c[\mathrm{rev/min}]}$$

Relationship between angular and rotational speed

$$r = \frac{1}{2}d$$

Relationship between radius and diameter

Feeds and Speeds (Speed Derivation)

$$\omega_{c[\mathrm{rev/min}]} = \frac{v_{[\mathrm{ft/min}]}}{\pi d_{[\mathrm{ft}]}}$$

Substituting values

$$d_{[\mathrm{ft}]} = \frac{1}{12} d_{[\mathrm{in}]}$$

Relationship between tool diameter in feet and inches

$$\omega_{c\left[\frac{\mathrm{rev}}{\mathrm{min}}\right]} = \frac{4v_{[\mathrm{ft/min}]}}{d_{[\mathrm{in}]}}$$

Final result – look familiar!

Feeds and Speeds

Cutting Speed
(SFPM = surface feet per minute)

Material Identity	High-speed Steel Cutting Tool	Carbide Cutting Tool
Plastics	500	800
Aluminum	300	600
Brass	200	400
Mild Steel	75	250
Stainless Steel	50	100

Feeds and Speeds

Feed Equation

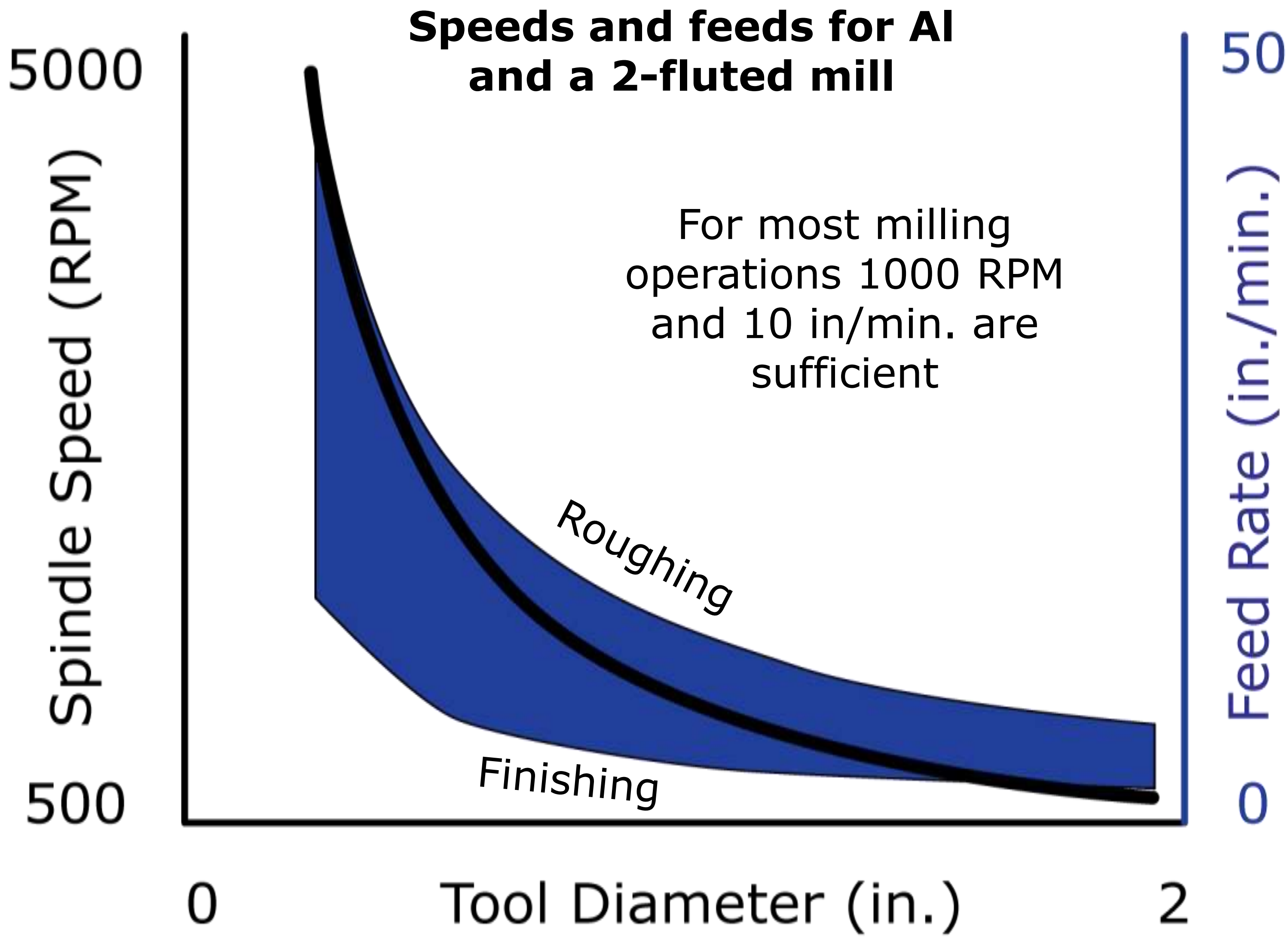
Roughing = 0.005”
Finishing = 0.001 – 0.002”

You set this

$$\text{Feed Rate}\left[\frac{\text{in}}{\text{min}}\right] = \text{Chip Load}\,[\text{in.}]\ \text{x}\ \text{Number of Teeth x Spindle Speed}[\text{RPM}]$$

Determined by the speed equation

Feeds and Speeds



Part Indication – Edge Finding