Tool Wear and Tool Life

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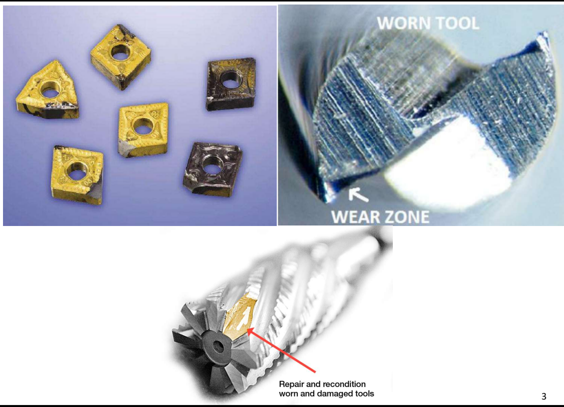
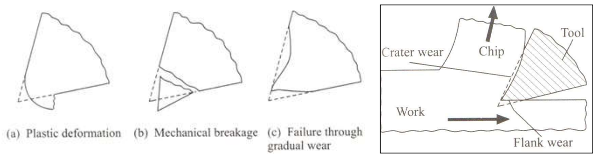
Outline

- Mechanisms of Tool wear
- Criteria for Tool Life
- Factors affecting Tool life
- Taylor's Tool Life equation

Wear of cutting tools



Tool wear and failure modes



Plastic deformation
- High Temperature at Chip Tool
- Work material with poor conductivity
- Tool tip melting

Tool fracture
- Gross Fracture and Edge Chipping
- Interrupted cutting
- Hard and brittle tool material

Preferred Mode

Gradual Tool Wear

Mechanism of Tool wear

Wear is the loss of material from a surface

Worn tool causes large power consumption and poor surface finish

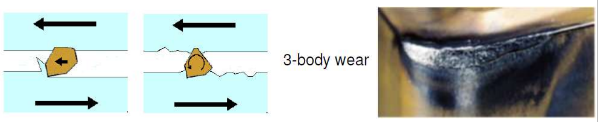
Tool wear occurs on

- Rake surface –Ccrater wear
- Flank surface – Flank wear

Tool wear mechanisms

- Adhesive wear,
- Abrasive wear,
- Diffusion wear,
- Corrosive wear,
- Fatigue wear

Abrasive wear

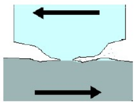


- Mechanical wear process due to loss of material by micro-cutting action
- If one of the surface contains hard particles, then during sliding, may dislodge materials from other surface by ploughing action
- Abrasive wear resistance increases with hardness

Adhesive wear

- When the bodies in contact are of similar nature, the asperities on the contacting surfaces tends to get welded
- Sliding causes fracture of these welded junctions and material is lost from both surfaces
- Mechanical wear process; wear particles generated from the softer of two contacting surfaces; characterized by metal transfer from softer to harder body.
- Archard's wear equation:
  - V: volume of wear
  - K: wear coefficient
  - L: sliding distance
  - N: normal load
  - H: hardness of the softer surface

$$V = K\left(\frac{LN}{3H}\right)$$



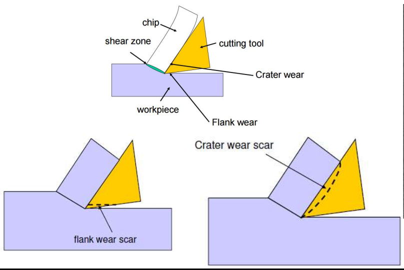
Diffusion and Corrosive wear

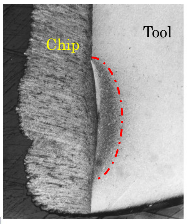
- Diffusion wear
  - Movement of atoms in metallic crystal lattice from higher to lower concentration
  - Diffusion rate increases exponentially with temperature
  - Wear due to diffusion is dominant at high temperature region, esp for high speed machining
- Corrosive wear:
  - Chemical reactions between the surface and environment (water, oxygen, acids, etc.)
  - Wear of cemented carbide cutting tool materials while cutting ferrous metals at high speeds

Crater and Flank wear

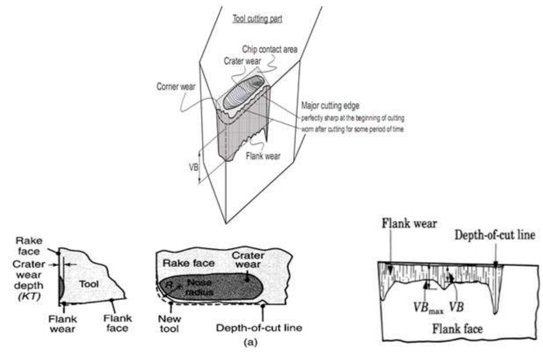
Crater wear: Scar / Pit on rake face of the tool
- Possible mechanisms: Adhesion, Abrasion, Diffusion (high speeds)

Flank wear: Scar on flank face of tool
- Possible mechanisms: Adhesion, Abrasion (rubbing of flank face against cut surface)



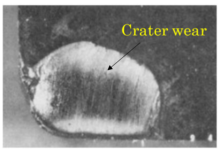


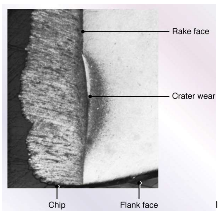
Crater wear and Flank wear

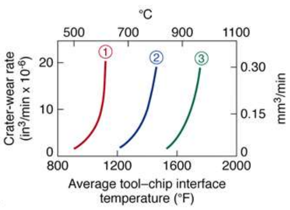


Crater Wear

- Diffusion is dominant for crater wear
- Crater wear rate increases with
  - Cutting temperature
  - Chemical affinity between tool and work
- Coating of hard materials help in reducing crater wear : TiN /Al2O3/TiCN

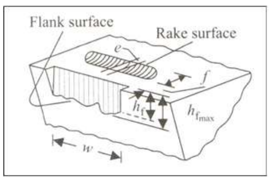






Flank and Crater wear – Failure criteria

End of tool life can occur by
- Catastrophic failure
- Progressive wear of flank and/or rake face of tool



ISO Criteria

Flank Wear

Vb (hf) = 0.3 mm Normal wear
hf max = 0.6 mm Irregular wear

Crater Wear

e = 0.06 + 0.3 f mm

sometimes depth of cut t is used in place of f

Assessing Tool Life

Inspection in Laboratory

- Crate wear measurement – Depth of crater
- Flank wear measurement – Length of Wear land

Indirect assessment in shops

- Number of pieces produced satisfactorily - Criteria
  - Surface finish
  - Vibration
  - Cutting force / power

Online Tool Life assessment

- Sensor based measurement and process control

Taylor's Studies on Tool Life

Tool Life vs Cutting Speed

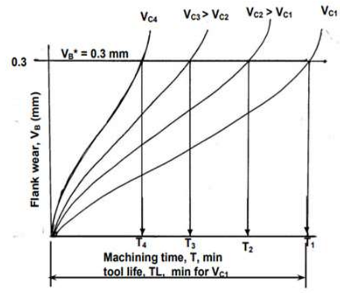


Figure 1: Growth of flank wear and assessment of tool life

F. W. Taylor

1856-1915

Tool Life vs Cutting Speed

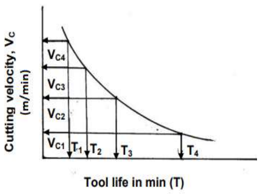


Figure 2: Cutting velocity - tool life relationship

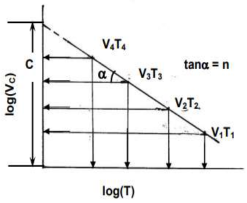


Figure 3: Cutting velocity vs tool life on a log-log scale

Taylor's Tool Life Equation

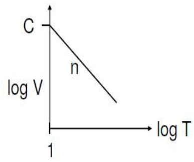
Taylor's equation

Relationship between cutting speed (V) and tool life (T)

$\boldsymbol{VT^n = C}$

n: Taylor's exponent, C: Taylor's constant

For HSS, n = 0.1, for WC, n = 0.2, for other ceramic n = 0.4



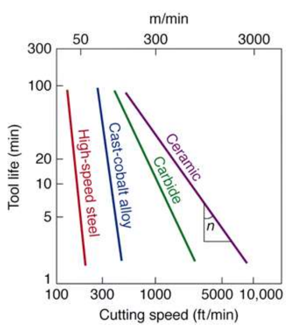
Range of Taylor's exponent n for different tool materials

High-speed steels	0.08-0.2
Cast alloys	0.1-0.15
Carbides	0.2-0.5
Coated carbides	0.4-0.6
Ceramics	0.5-0.7

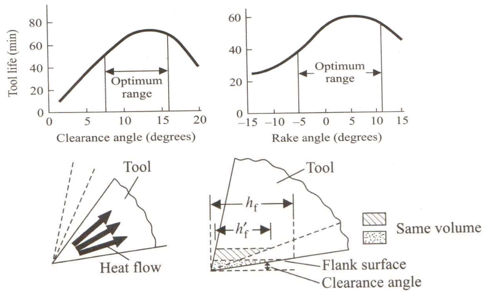
$$VT^n = C$$

n =Taylor's tool life exponent.
C =Taylor's tool life constant.
T =Tool life (min)
V = cutting speed (m/min)

Tool-life Curves for Tool materials



Effect of tool angles on tool life



Rake angle increases, sharper tools, cutting forces reduces, however if rake angle is too high, tool becomes thinner, area available for thermal conduction reduces, higher tool wear, reduced tool life

Extended Taylor's tool life equation

Experiments demonstrated that feed rate (f), and depth of cut (d) also affect the tool wear and thus tool life (T)

Extended Taylor's equation:

$$\text{T: } VT^{n}d^{n1}f^{n2} = C'$$
$$n, n_1, n_2 : 0.1 - 0.4, C' > 100$$

Work material	Tool material	C'	n	n1 p	n2 q
Steel	WTiC 10% Co	273	0.2	0.2	0.15
		227		0.35	
		221		0.45	
	WTiC 6% Co	292	0.18	0.3	0.15
Cast iron	WC	324	0.28	0.4	0.2

Example

In a production turning operation, the work part is 125 mm in diameter and 300 mm long. A feed of 0.225 mm/rev is used in the operation. If cutting speed = 3.0 m/s, the tool must be changed every 5 work parts; but if cutting speed = 2.0 m/s, the tool can be used to produce 25 pieces between tool changes. Determine the Taylor tool life equation for this job. What will be the feed if the same tool can be used for machining 50 pieces at cutting speed of 5.0 m/s?

Machining time per piece tm = $\frac{L}{Nf}$ L length in mm, N : RPM, F feed mm/rev

Cutting Speed V = $\frac{\pi DN}{1000}$ D diameter in mm, V in m/min

Taylor's equation $V\,T^{n} = C$, T in min