Cutting Tool Materials

Various cutting materials has been used in industry for different applications. The important characteristics expected of cutting tool material

1- Higher hardness

2 -Hot hardness

3- Wear resistance-

4- Toughness

5- Low friction

6- Thermal characteristics

Types of Materials

Carbon Tool Steel

-0.6 -1.5% carbon and very small alloy additions such as manganese

-Speed 6- 9 m/min

High speed steel

Carbon, Tungsten, Molybdenum, Chromium

Speed 30 - 45m/min

Cemented carbides

- High hardness
- Higher young's modulus

-Speed 70-120 m/min

Ceramics

-Speed 250-300 m/min

Diamond

- Can be used as a cutting tool material
- High tool life

Requirements When Machining with Ceramics:

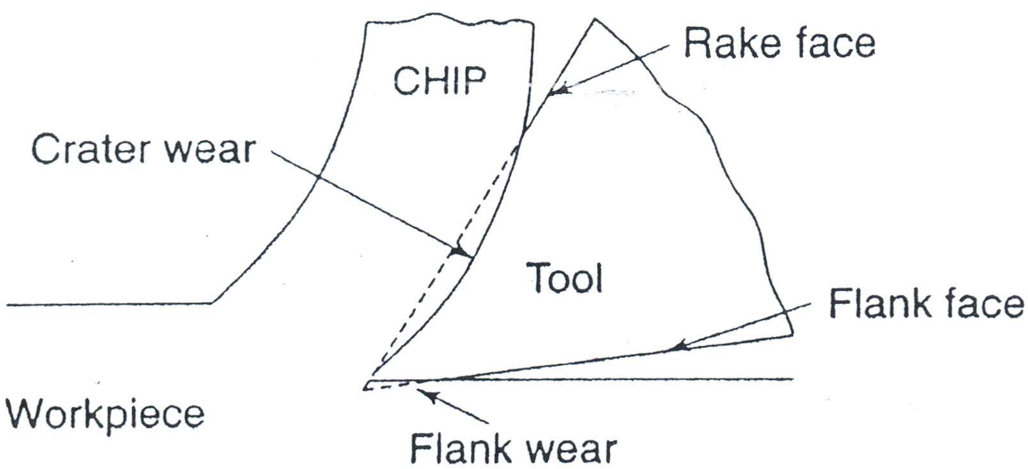
- Using the highest cutting speed recommended
- Use rigid machines
- Machining rigid work-pieces
- Ensuring adequate power supply
- Using negative rake angle
- Keeping the overhang of the tool holder to minimum
- Using a large nose radius
- Taking a deeper cut with a light feed
- Avoiding coolants with aluminum oxide based ceramics
- Reviewing machining sequences while converting to ceramics and if possible introducing chamfers or reduce feed rate at entry

Tool Wear And Tool Life

A tool gets worn out due to long term usage. There are two major types of wear found in tools:

1- Crater wear

2- Flank wear



Cutting tools are subjected to extremely sever cutting conditions:

- Metal to metal contact
- Very high stress
- Very high temperature
- Virgin metal
- Very high temperature gradients
- Very high stress gradients

TOOL LIFE

- Tool life represented the useful life of the tool
- The tool life can be specified by any of the Following measurable quantities:

1-Actual cutting time to failure
2-Length of work cut to failure
3- Volume of metal removed to failure
4-Number of components produced
5-Cutting speed for a given time to failure

Tool Failure Criteria

- Chipping or fine crack at the cutting edge
- Wear land size
- Crater depth or width
- A combination of the above two
- Volume or weight of material worn off the tool
- Total destruction of the tool

Based on Consequence of A Worn Tool

- Limiting value of surface finish

- Limiting value of change in component Size

- Fixed increase in the cutting force or power required to perform a cut.

Tool Life Equation

Taylor equation based on his experimental work

$$VT^n = C$$

Where:

V = Cutting Speed m/min

T = Tool Life in Minutes

C and n = Constant

This formula was extended by a number of researchers

$$V\,T^n\,f^{n_1}\,d^{n_2} = C$$

Constants for extended tool life equation

Tool material	*Work material*	*Exponent for*			*Constant C*
ISO Grade	*AISI*	*Tool life, n*	*Feed, n_1*	*Depth of cut, n_2*	
P01, P10	1020	−0.38	−0.06	−0.10	1150
P20, P30	1020	−0.38	−0.17	−0.11	780
P01, P10	1045	−0.22	−0.21	−0.11	350
P20, P30	1045	−0.22	−0.34	−0.12	226

Example:1

In a tool wear test with a high speed steel cutting tool. The following values of tool life were obtained:

Tool Life min	Cutting Speed Meter / min
30	25
1.5	70

Calculate the values of n and C of Taylor's equation

Solution

$VT^n=C$

$\log V + n*\log T = \log C$

when: $T=30$ and $V=25$

$\log 25 + n \log 30 = \log C$

$1.3979 + n*1.477 = \log C$ (equation-1)

when: $T=1.5$ and $V=70$

$\log 70 + n \log 1.5 = \log C$

$1.8451 + n*0.176 = \log C$ (equation-2)

Equation-1 = Equation-2

1.3979 +n*1.477 =1.8451 +n*0.176

n=0.34472

Substitute in equation-1

1.3979 +0.344*1.477 = log C

log C =1.9059

C= 80.50

$$V\ T^{0.344} = 80.50$$

Example:2

A carbide cutting tool lasted for (2) hours while machining mild steel work material at 45 meter / min.

a- Compute the tool life if a similar tool is used for machining mild steel at 20% higher speed.

b- Also, what will be the value of cutting speed if the tool required to machine for (3) hours without failing.

(Assume that n=0.27)

Solution

$V T^n = C$

$\log V + n \log T = \log C$

$\log 45 + 0.27 \log 120 = \log C$

$1.6532 + 0.27*2.0791 = \log C$

$\log C = 2.215$

$C=163.89$

$V T^{0.27} = 163.89$ #

a- When speed increases by 20%

$V = 1.2*45 = 54$ meter/min

$\log 54 + 0.27 \log T = \log C$

$\log 54 + 0.27 \log T = \log 163.89$

$1.7324 + 0.27 \log T = 2.215$

$0.27 \log T = 0.4826$

$\log T = 1.7874$

$T = 61$ minutes

b- When T =3 hours = 180 minutes

$\log V + 0.27 \log 180 = \log C$

$\log V + 0.27 * 2.255 = 2.215$

$\log V = 1.606$

$V = 40.27$ meter/ min

$V = 40$ meter/ min

Example:3

In a laboratory test on turning operation, the following data have been recorded at a depth of cut of 2mm:

Cutting Speed Meter / min	Tool Life min	Feed mm/rev
100	120	0.1
130	50	O.1
100	70	0.12

A tool life equation is to deduced by computing the values of n1, n2, n3 in the relationship:

$V\,T^{n}\,f^{n1}\,d^{n2}=C$

Where C= 2.22

Solution:

Tool life equation:

$$V\,T^{n}\,f^{n1}\,d^{n2}=C$$

$100*120^{n}*0.1^{n1}*2^{n2} = C$ Equation -1

$130*50^{n}*0.1^{n1}*2^{n2} = C$ Equation-2

$100*70^{n}*0.1^{n1}*2^{n2} = C$ Equation -3

Equation 1 = Equation 2

$100*120^{n}*0.1^{n1}*2^{n2} = 130*50^{n}*0.1^{n1}*2^{n2}$

Then: $100*120^{n} = 130*50^{n}$

$\log 100 + n \log 120 = \log 130 + n \log 50$

n= 0.3

Equation 2 = Equation 3

n1=0.4

Substitute in Equation-1

n2=-6.236

Machinability

- Machinability is the characteristic of the work material expressing its ease of machining.
- Hard work material are difficult to machine
- Hardness alone would not be able to specify the machinability
- It depends on the other characteristics such as tool materials used, process parameters. , .. , ...

Surface Finish

The actual surface finish obtained depends on the factors such as:

- The cutting process parameters, speed , feed, and depth of cut.
- The geometry of the cutting tool
- Application of cutting fluid
- Work and tool material characteristics
- Rigidity of the machine tool and consequent vibration

SURFACE FINISH
Typical Applications

MACHINE DESIGN

SRF-68-02

Old Surface Finish Symbol	Roughness Numbers No. [1]	Microns [2]	Micro-Inches	Typical Applications
∼	N 12	50	2000	Smooth non-machined surfaces with nice appearance - Surfaces with no special requirements but to be touched by the hand.
▽	N 11	25	1000	Non-mating surfaces - Surfaces receiving further machining other than grinding
	N 10	12.5	500	
▽▽	N 9	6.3	250	Surfaces taken as datum for subsequent machining - Surfaces to be finished by grinding - Surfaces bolted to a gasket.
	N 8	3.2	125	Normal mating surfaces with no relative motion, no sealing or contact accuracy.
	N 7	1.6	63	Guiding or centring surfaces with occasional relative motion Low speed bearing (sliding) surfaces · Surfaces finished by scraping to form a metal - to - metal joint
▽▽▽	N 6	0.8	32	Accurate centring surfaces without relative motion - Low speed low pressure bearing surfaces
	N 5	0.4	16	Medium speed (up to 3 m/sec) medium pressure (up to 5 kp/cm²) bearing surfaces - Sliding surfaces with restricted wear.
	N 4	0.2	8	High-speed heavily-loaded sliding bearings - Interior surfaces of hydraulic cylinders - Centring surfaces of fixtures and chucking cones.
▽▽▽▽	N 3	0.1	4	Ground screw threads and gear teeth - Surfaces for cutting punches.
	N 2	0.05	2	Centring surfaces of high accuracy : main spindles, arbours - Surfaces for cutting dies.
	N 1	0.025	1	Sliding surfaces with extremely low wear · Rolling bearing surfaces · Measuring instruments of high precision.

1) In accordance with ISO DR 1302-1967.

2) Preferred Series of ISO TC/57

Accuracies achievable in machining operations

Machining operation		*Accuracy*
Turning		± 25 μm
Shaping, Slotting		± 25 μm/side
Planing		± 65 μm/side
Milling		± 12 to 25 μm
Drilling in drill press	Location	± 250 μm
	Hole	+ 125 μm
	Jig hole	+ 50 μm
Drilling in lathe	Location	± 12 μm
	Hole	+ 2.5 μm
Boring		± 2.5 μm
Internal grinding		± 2.5 μm
Reaming		+ 25 μm
Reaming with jig		+ 12.5 μm
Jig boring	Hole	± 2.5 μm
	Location	± 5 μm
Cylindrical and surface grinding		± 2.5 μm
Thread cutting products		± 50 μm
Broaching		± 12.5 μm
Lapping		± 5 μm
Honing		± 12.5 μm
Super finishing		± 0.5 μm

Achievable surface finishes

Operations	Roughness (R.M.S.) microns										
	25	12.5	6.25	3.2	1.6	0.8	0.4	0.20	0.10	0.05	0.025
Flame cutting, Sawing	X	X									
Hand grinding	X	X	X								
Filing, Disc grinding		X	X	X	X						
Turning, Shaping, Milling		X	X	X	X	X					
Boring			X	X	X	X	X				
Drilling			X	X							
Surface grinding			X	X	X	X	X				
Cylindrical grinding					X	X	X	X			
Honing, Lapping							X	X	X	X	
Polishing							X	X	X	X	
Super finishing								X	X	X	X
Buffing									X	X	X

Cutting fluid

Why??

- To reduce the friction between the tool and the work-piece and chips
- Absorb heat generated
- Wash way chips

Results??

- Reduce power consumption
- Improve the surface finish
- Increase the tool life

Specifications

- It heat absorbed
- Stability
- Odorless
- Harmless to bearing
- Low viscosity to separate
- Good lubricant
- Neutral
- Harmless to scale
- Non corrosive
- Low priced

Types of cutting fluids

- Water
- Straight oils
- Chemical additive oils
- Stream of compressed air
- Soluble oil
- Mixed oils
- Solid (wax)