Machinablity

Defination by "Woldman & Gibbons;-

"The most machinable metal is one which will permit the fastest removal of the largest amount of metal per tool grind (without resharpening of the cutting tool) with satisfactory surface finish".

It is the material property that indicates how machinable a material is attempt to express this property quantitatively by a single parameter has elude the tool engineers for year, it is considered that machinability is a property mainly concerned with the work material, but is also affected by the cutting speed, dimensions of cut, tool material, nature of tool work engagement, tool geometry, coolants, rigidity to the machine tool and any particular ~~er~~ criterion too evaluate machinability, the work material variable that influence machinability are its chemical composition, material property (such as yield strength, hardness, work hardening characteristics, toughness, etc.) metallurgical characteristics (Micro-structure, grain size, heat treatment, inclusion, etc.), shape and dimension of the workpiece and its condition (cast and forged.).

Evaluation of Machinability No direct method of determining the ease and difficulty of removing metal and therefore, use of indirect methods have been made to evaluate machinability of metal. Some of the methods suggested ~~for~~:-

a) Tool life / Tool wear or the cutting speed for a given tool life.

b) Specific Power Consumption

(c)

c) Magnitude of the cutting force generates during m/cing.
d) Quality of the m/ced surface.
e) Dimensional stability of the finished work
f) Shear angle or chip thickness ratio
g) Ease of chip disposal
h) Chip hardness
i) Surface Finish

Mechanism Of Tool Wear

The common mechanisms responsible for causing wear are the following:-

1) **Abrasion** - It is a type of Mechanical wear. Hard particles on the underside of the sliding chip, which are harder than the tool material, plough into the relatively softer material of the tool face and remove metal particles by mechanical action. The material of the tool face is softened due to the high temp. The hard particles present on the underside of the chip may be:

   a) Fragments of hard tool material
   b) Broken pieces of BUE, which are strain hardened
   c) Extremely hard constituents like carbides, oxides, scales, etc., present in the work material.

2) **Adhesion** - Due to the excessive pr a lot of friction occurs b/w the sliding surface of the chip and the tool face. Extremely high localised temp. causing metallic bond b/w the materials of the tool face and the chip. ~~but~~ Due to the excessively high temp. at the chip-tool interface a metallic bond takes place b/w the chip material and tool material at the contact points in the form of small spot welds. When the chip slides, these small welds are broken. But this separation is not along the line of contact. A small portion of the welded tool contact is also carried away by the sliding chip. Thus, small particles from the

tool face continue to be separated through this phenomenon and carried away by the chip by adhesion to its underside. the ~~ma~~ amount of material so tranferred from the tool face to the chip will depend upon the contact area and relative hardness of the chip and the tool materials.

Note :- Surfaces of both the chip underside and the tool face, although appear to be smooth apparently, are microscopically rough. therefor, the contact b/w these surfaces is not truly a surface contact but a point contact.

3) Diffusion - Solid State diffusion, which consits of transfer of atoms in a metal crystal lattice, is another cause of wear. The transfer of atoms takes place at elevated temperatures from the area of high concentration to that of low concentration. The favourable condition for diffusion is provided by the rise in localised temp. over the actual contact area b/w the chip underside and the tool face. In such a condition the metal atom are transferred from the tool material to the chip material at the points of contact. The amount of diffusion depends upon:-

a) Temp. at the contact area b/w the tool face and the chip.

b) Period of contact b/w tool & chip

3) Bonding affinity b/w the materials of tool & chip.

4) Chemical Wear - Cutting fluid is used in the process, which is chemically active to the material of the tool.

- Chemical reaction taking place b/w the cutting fluid and tool material, leading to a change in the chemical composition of the surface material of the tool.

Tool Failure If tool is not giving a satisfactory performance, it is indicative of the tool failure.

effects of tool failure

- Extremely poor surface finish
- Higher consumption of power
- Work dimensions not being produced as specified.
- Overheating of cutting tool.
- Burnishing band on the work surface.

Forms/Types of tool failure

1) Thermal Cracking & Softening ~~Be~~ Bcoz of heat generated in metal cutting process, tool tip and the area closer to the cutting edge becomes very hot.

- At high temp. tool material starts deforming plastically at the tip and adjacent to the cutting edge under the action of the cutting pr. and high temp.
- Main factor for resposible for this
  + High cutting speed
  + High feed rate
  + Excessive depth of cut
  + Smaller nose radius.
  + Choice of a wrong tool material.

Crack & ~~flucti~~ Fluctuations in temp. and severe temp. gradients the tool material is subjected to local expansion and contraction. This gives rise
- ~~Bcoz of this, rise to the~~
to the setting up of Temp. stresses or thermal stresses, due to which cracks are developed. These crack are thermal crack.

2) Mechanical chipping of the tool nose or cutting edge.

·Ressons are - Too high cutting pr.
- Mechanical Impact
- Excessive wear
- Too high vibraction.
- Chatter..
- Weak tip, etc

3) <u>Gradual Wear</u> ~~After useing tool in som~~

On every time using tool, lost some amount of weight or mass due to wear.

- <u>Crater Wear</u> The principal region where wear takes place in a cutting tool is its face, at a small distance from ~~the~~ its cutting edge.
Wear generally takes place while m/cing
+ ductile materials, e.g. steel & steel alloys.
+ Resultant feature of this type of wear is the formation of crater or depression at tool chip interface.

- <u>Flank Wear</u> It occurs due to abrasion b/w the tool flank and the w/p and excessive heat generated.
- This type of wear ~~comes in~~ find in
  + Brittle material.
- Area subjected to flank wear is known as wear land.
- Its come mainly on the tool nose and front and side relief face.
- Magnitude of ~~th~~ wear depends upon the relative hardness of the w/p and tool material.
- Due to this wear tool loses its dimensional accuracy, so energy consumption is increased and poor surface finish.

Tool Life

During m/cing, the cutting edge of the tool gradually wears out and its does not perform satisfactory. When the wear reaches a certain stage it is said that the tool has lost its utility and its life is over. The period during which a tool cuts satisfactory is called its tool life.

– The common method for the measurement of tool life quantitatively are:

- Machine Time
- Actual Cutting time
- Average length of cut per tool edge
- Average number of identical components m/ced per tool edge
- Average volume of metal removed per cutting edge
- Cutting speed

F.W. Taylor developed the relationship b/w tool life and cutting speed –

$$VT^n = C \qquad \text{——— (1)}$$

↳ Taylor's tool life equation

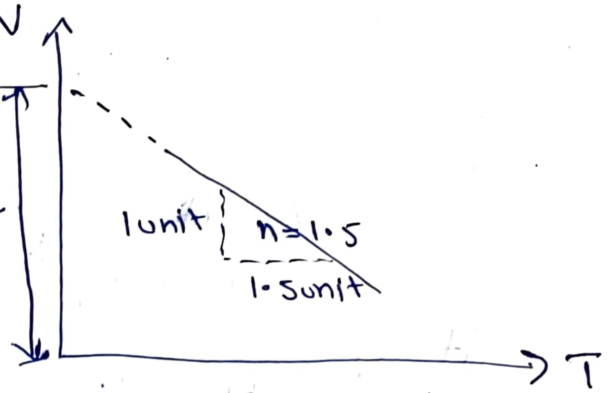
V = cutting speed, m/m

T = Tool life, m

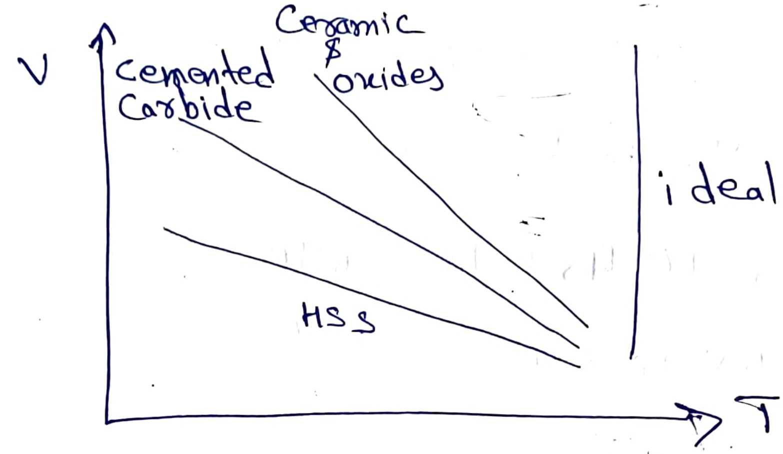
n = ~~exe~~ exponent

C = Constant depend upon the cutting condition and work material, known as M/cing Constant

- m/cing at high cutting speed leads to much earlier failure of the tool.
- At low speed low production rate.



Tool life plot (log-log scale)



Log-log tool plots for various cutting tool material.

In log-log representation of eq (i) -

$$\log VT^n = \log C$$

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

$$n = \frac{\log C - \log V}{\log T}$$

At $T = 1$,

$\log T = 0$

$\therefore \log V = \log C$

Q) In m/cing test with two tools A & B, the exponent n and constant C were found to be 0.45 and 90 for tool A and 0.3 and 60 for tool B. Determine the cutting speed above which tool A will have higher tool life than tool B.

Sol) Let

V = Cutting speed above which tool A will have higher tool life than tool B.

∴ at V, $T_A = T_B$

$$VT_A^{0.45} = 90$$
$$VT_B^{0.3} = 60$$

Taking log both side.

$$\ln V + 0.45 \ln T_A = \ln 90 \quad \text{—(i)}$$
$$\ln V + 0.3 \ln T_B = \ln 60 \quad \text{—(ii)}$$

Divide (i) & (ii)

$$\ln T_A - \ln T_B = \frac{\ln 90 - \ln V}{0.45} - \frac{\ln 60 - \ln V}{0.30}$$

As $T_A = T_B$, at cutting speed of V, we get

$$0 = \frac{0.3 \ln 90 - 0.3 \ln V - 0.45 \ln 60 + 0.45 \ln V}{0.45 \times 0.3}$$

$$0.15 \ln V = 0.4925$$

$$V = 26.67 \text{ m/min.}$$

Modified Taylor's Constant C_v

Tool life also affected by feed & depth of cut,

$$T = \frac{C_1}{V^m}$$ —— speed Cutting

$$T = \frac{C_2}{t^q}$$ —— Depth of cut

$$T = \frac{C_3}{s^p}$$ —— feed.

Combining all above three eq.,

$$T = \frac{C_4}{V^m t^q s^p}$$

$$V = \frac{C_v}{T^{\frac{1}{m}} s^{y_v} t^{x_v}}$$ — Taylor's Generalized tool life eq.

$\frac{1}{m} = n$ — Taylor's tool life exponent

$x_v = \frac{q}{m}$ — exponent of depth of cut

$y_v = \frac{p}{m}$ —— exponent of feed

C_v = modified taylor's constant

Max. impact on tool life is that of cutting speed followed by feed & depth of cut in the given order, $m > p > q$, therefor $y_v > x_v$. The value of x_v & y_v depend on the type of cutting tool, work material. and m/cing conditions.

Q) The following tool life equation was obtained for HSS tool, $VT^{0.13}S^{0.6}t^{0.3} = C$. Tool life of 60 min was obtained at $V = 40$ m/min, $S = 0.25$ mm/rev and $t = 2$ mm. Calculate the effect of tool life if V, S and t are together increased by 25 percent.

Sol Given Data.

$$VT^{0.13}S^{0.6}t^{0.3} = C$$

$V = 40$ m/min

$S = 0.25$ mm/rev

$t = 2$ mm

$T = 60$ min

$$40 \times 60^{0.13} \times 0.25^{0.6} \times 2^{0.3} = C$$

$$C = 36.5$$

With Increase of 25%.

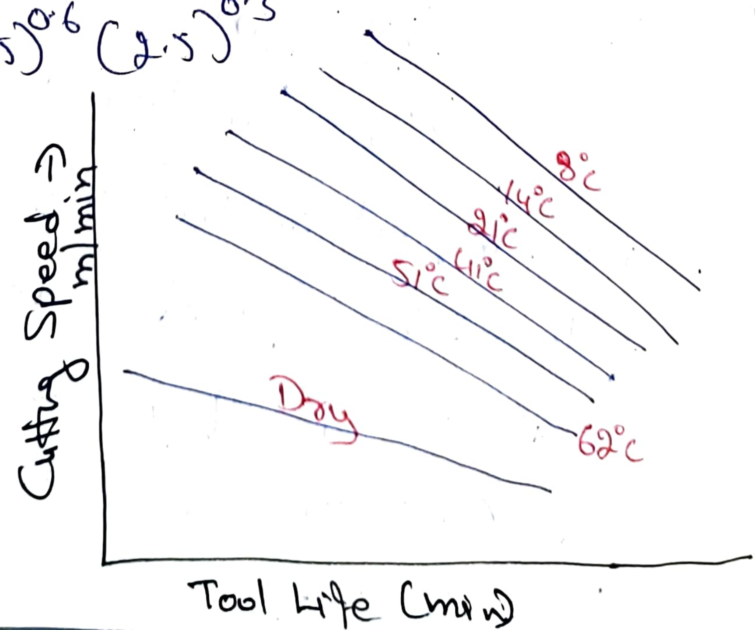
$V = 1.25 \times 40 = 50$ m/min, $S = 1.25 \times 0.25 = 0.3125$ mm/rev

$t = 1.25 \times 2 = 2.5$ mm

$$T = \frac{36.5}{50(0.3125)^{0.6}(2.5)^{0.3}}$$

$T = 2.30$ min.

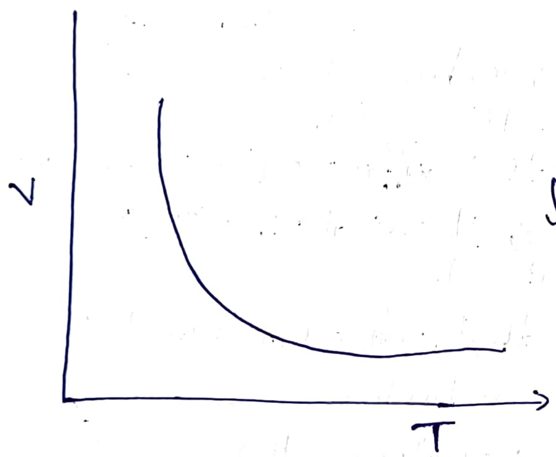
Effect of Cutting Fluid on Tool Life. ⟶



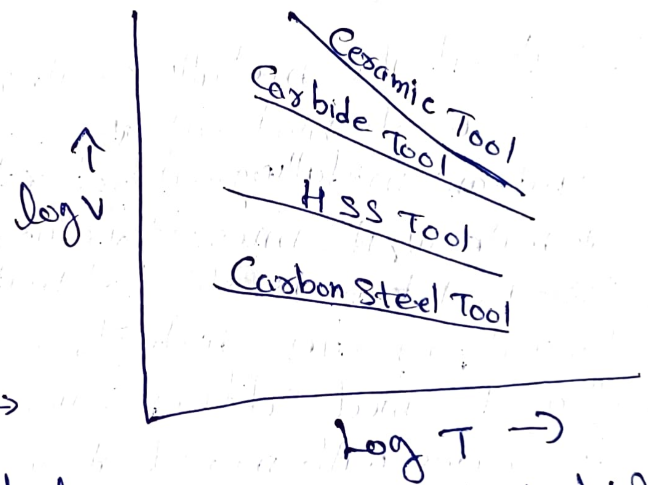
Effect of Various Factors on Tool life.

i) Cutting Speed ii) Feed & depth of cut
iii) Tool Geometry iv) Tool material
v) Work material vi) Nature of cutting
vii) Rigidity of m/c tool & work.
viii) Cutting fluids.

i) Cutting Speed Max. effect on tool life. the tool life varies inversely as the cutting speed i.e. higher cutting speed the smaller the tool life.



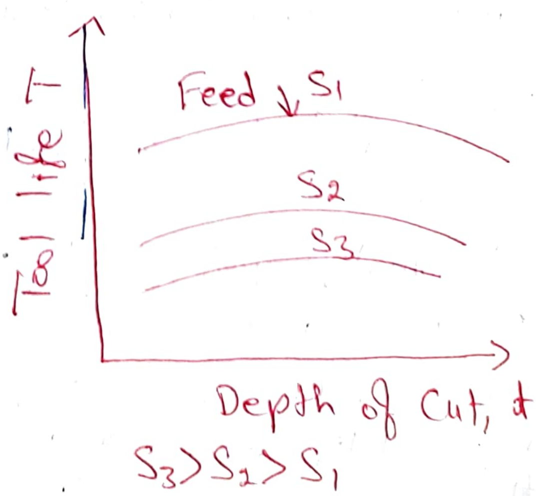
Curve Showing Parabolic Reduction in tool life with the increase in cutting Speed.



Cutting speed - tool life curves for different tool materials.

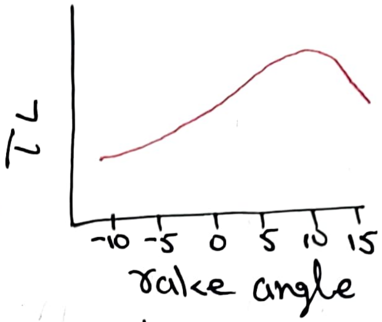
ii) Feed & Depth of cut.

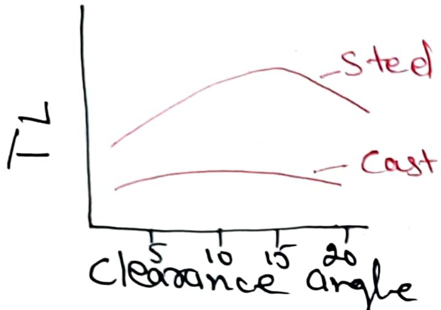
Increase in feed also reduce the tool life as it results in increased cutting force and cutting temp.

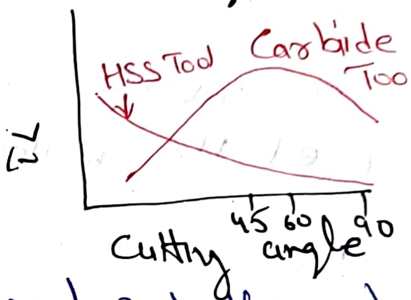


iii) Tool Geometry Tool life of tool depends on both material and geometry. Proper selection of primary geometrical features enables to obtain such higher tool life through.

a) Reduction in Cutting forces and heat generation
b) Better heat dissipation.
c) Favourable Stress distribution
d) Prevention of BUE
e) More effective cutting fluid action







iv) Work Material The metallurgical, mechanical and thermal properties of work material affect the tool life.

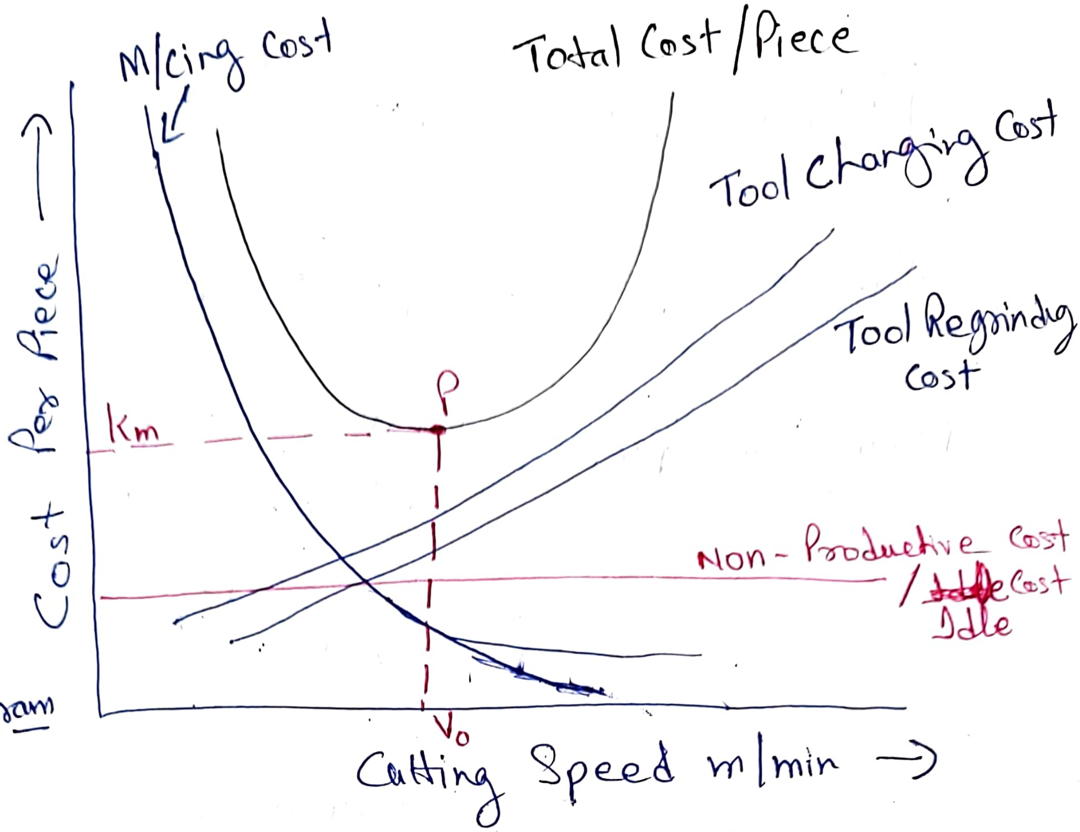
a) The significant metallurgical factor that affect TL is - composition of work material, its microstructure, chemical affinity and chemical aggressiveness towards the tool material.
b) mechanical properties - high strength, hardness and work hardenability as well as too much softness cause reduction in tool life.
c) TL decreases with more heat resistivity of the work material.

v) Tool Material Same as work material.

a) Tools that are chemically inert or stable against the work material, atmospheric gases and cutting fluid, undergo lesser and slower damage and provide ~~tog~~ longer TL.
b) Finer and refined microstructure of material renders improvement in TL.
c) Mechanical Properties - its strength and hot strength, high hardness and hot hardness, as well as high fracture toughness enhance the TL.
d) Thermal properties - low thermal conductivity at the surface but high at its core, if feasible, is ideal for TL

vi) Cutting Fluid Proper Selection & method of application can raise tool life drastically through cooling, lubrication & cleaning of the zone from chip and debris.

Economics Of Metal Machining



Production Cost diagram

> Cost/Piece = Idle Cost Per Piece + Cutting cost Per Piece + Tool Changing cost Per Piece + Tool regrinding Cost per Piece.

K_1 = (Direct labour cost + overhead charges) in Rs/min

K_2 = Cost of tool per grind in Rs.

L = Length of m/cing in mm

D = M/ced dia of workpiece (mm)

V = Cutting speed, in m/min

f = feed rate (mm/rev)

T_i = Idle time per piece, (min)

T_c = Tool changing time (min)

Idle cost/piece = (Direct labour cost + Overhead) × Idle Time

| Idle cost/piece = $k_1 \times T_i$ |

Cutting cost/piece = $k_1 \times$ (Machining time/piece)

M/cing Time/piece = $\frac{\text{Length of m/cing}}{\text{Feed rate} \times \text{r.p.m}}$

$$= \frac{L}{f \times N} \quad \left[V = \frac{\pi D N}{1000} \text{ or } N = \frac{V \times 1000}{\pi D} \right]$$

$$= \frac{L}{f \times \frac{V \times 1000}{\pi D}}$$

| M/cing time/piece = $\frac{\pi D L}{f . V . 1000}$ |

| Cutting cost/piece = $k_1 \frac{\pi D L}{f . V . 1000}$ |

Tool changing cost/piece = (Direct cost × overheads) × Tool failures per workpiece × Tool changing time for each failure

Taylor's tool life.

$$VT^n = C$$

$$T = \frac{C^{1/n}}{V^{1/n}}$$

Total number of tool failuer (T_x) per workpiece

$$T_x = \frac{\text{M/cing time per piece}}{\text{Tool life}}$$

$$T_x = \frac{\pi DL / 1000 f V}{C^{1/n} / V^{1/n}}$$

$$T_x = \frac{\pi DL V^{\frac{1}{n}-1}}{1000 f V \cdot C^{1/n}}$$

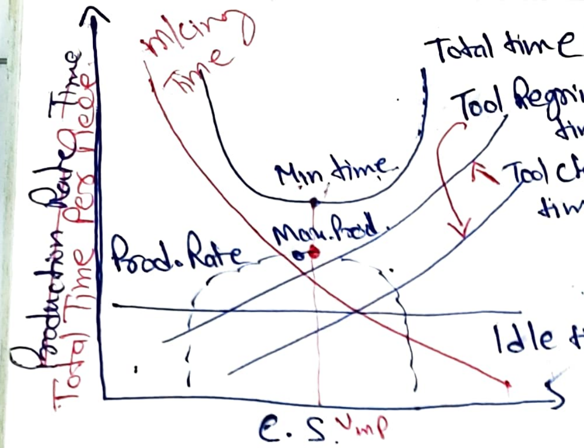
$$\text{Tool changing cost/piece} = k_1 \frac{\pi DL (V)^{\frac{1}{n}-1}}{1000 f V (C)^{1/n}} T_c$$

Tool Regrinding cost/piece (T_R) = Cost of tool per grind × Total number of tool failure per workpiece

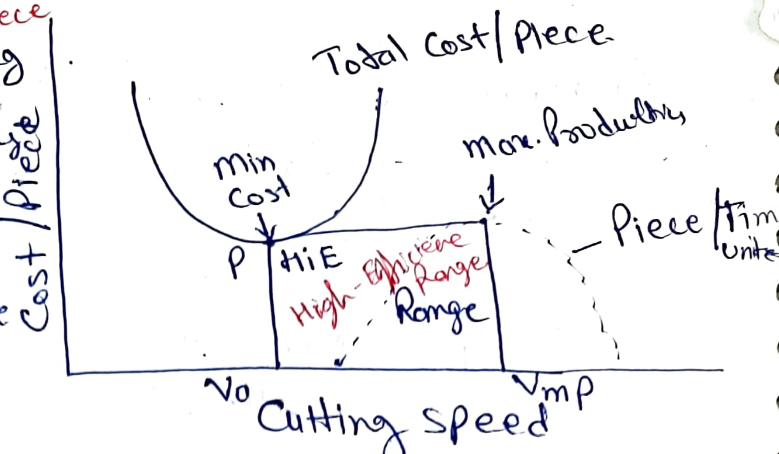
$$T_R = k_2 \frac{\pi DL (V)^{\frac{1}{n}-1}}{1000 f V (C)^{1/n}}$$

Total Cost per piece (k)

$$k = (k_1 + T_1) + k_1 \frac{\pi DL}{1000 f V} + k_1 \frac{\pi DL (V)^{\frac{1}{n}-1}}{1000 f V (C)^{1/n}} \cdot T_c + k_2 \frac{\pi DL (V)^{\frac{1}{n}-1}}{1000 f V (C)^{1/n}}$$



Total time in m/cing



Gilbert's HiE - High Efficiency Range (Combination of total cost/Piece & max. Production time)

For min. Cost

$$\text{Cutting speed } (V_0) = \frac{C}{\left[\left(\frac{1}{n}-1\right)\left(\frac{K_1 \times T_c + K_2}{K_1}\right)\right]^n}$$

$$\text{Tool life } (T_{mc}) = \left(\frac{1}{n}-1\right)\left(\frac{K_1 \times T_c + K_2}{K_1}\right)$$

For Max. Production

$$\text{Cutting speed } (V_{mp}) = \frac{C}{\left[\left(\frac{1}{n}-1\right)T_c\right]^n}$$

$$\text{Tool Life } (T_{mp}) = \left(\frac{1}{n}-1\right)T_c$$

Time
Unit

Q) During m/cing of a component on Lathe the data obtained and those available otherwise are: M/cing Costant (C) = 80, Tool Changing time = 5 min, Tool regrinding time = 3 min, Tool depreciation Cost = Rs.1·20 Per grind, operating cost = 25 paise/min, Labour + Overheads per min. = 20 Paise, work loading and unloading = 30 sec, Feed = 0·25 mm/rev exponent (n) = 0·25, Job Length = 500 mm, m/ced all over in 4 passes, Cutting Speed = 30 m/min, Work dia. = 60 mm, Idle time/workpiece = 4 min., tool grinding cost = Rs. 1 Per grind.

Calculate:- i) Optimum Cutting speed
ii) Tool life (min. ~~Cost~~ optimum cutting speed)
iii) Cutting speed (Max. production)
iv) Tool life (Max. production)
v) M/cing cost
vi) Tool Changing cost
vii) Tool life
viii) Idle cost
ix) Tool regrinding Cost
x) Total Cost of production 1000 Components.

Sol) i) Cutting Speed (min. Cost)

$$V_0 = \frac{C}{\left[\left(\frac{1}{n}-1\right)\left(\frac{K_1 \cdot T_c + K_2}{K_1}\right)\right]^n}$$

$= 50 \cdot 5$ m/min.

ii) $VT^n = C$

$$T = \left(\frac{C}{V}\right)^{1/0.25} = 6 \cdot 35 \text{ min.}$$

iii) $V_{mp} = \dfrac{C}{\left[\left(\frac{1}{n}-1\right)T_c\right]^n}$

$= 47.6$ m/min

iv) $T_{mp} = \left(\frac{1}{n}-1\right)T_c = 15$ min.

v) M/cing ~~cost~~ time / piece $= \dfrac{\pi DL}{1000 f V} = 50$ min.

M/cing Cost / piece $(K_m) = K_1 \times 50$

$=$ Rs. 10 / piece

vi) $T = \left(\frac{C}{V}\right)^{1/n} = \left(\frac{80}{30}\right)^{\frac{1}{0.25}} = 1.28$ min.

vii)

$T_{CT} = K_1 \times$ Tool failure per work-piece $\times T_c$

$= K_1 \times \dfrac{\text{M/cing time}}{\text{Tool life}} \times T_c$

$= 20 \times \dfrac{50}{1.28} \times 5$

$=$ Rs. 39.06 / Piece.

viii) Idle cost $= K_1 \times T_1$

$= 0.80$ P / piece

ix) TR = Cost / grind × No of tool failure / piece

$= K_2 \times \dfrac{\text{M/cing time}}{T}$

$=$ Rs 39.06 per piece

x) ₹ K = 88.92

K (1000 piece) = Rs 88920.00

Cutting Fluid During metal cutting heat is generated as a result of the work done. Heat is carried away from the tool and workpiece by means of cutting fluids which at the same time reduce the friction b/w the tool-chip and tool-work and also facilitates the chip formation.

Functions of Cutting Fluid i) It cools the cutting tool and workpiece
ii) It lubricates the cutting tool and thus reduces the "μ" b/w chip – tool interface.
iii) The use of a cutting fluid result in better surface finish
iv) Cutting force requirement reduce bcz of less friction and less power consumption.
v) It caues the chips to break up into small pieces.
vi) It washes away the chip from the tool.
vii) It prevents corrosion of work & m/cine
viii) Reduce thermal distortion of the work and permit improved dimensional control.

Properties of Cutting Fluid i) It should have a high specific heat, high heat conductivity and high film coefficient.
ii) Good lubricant properties to reduce frictional forces.
iii) odorless. iv) non-corrosive. v) non-toxic vi) low viscosity to permit free flow of the liquid. vii) Stable in use & storage
viii) Permit clear view of work which is specially desireable in precision work.
ix) Safe particularly with regards to fire and accident hazards

Types of Cutting Fluid

- Water based
  - Soluble Oil
    - 1–5% mixed with water
    - excellent cooling
    - low cost
    - low lubricating
  - water — high corrosive
  - Soda Solutions – used in Grinding
- Straight or Neat oil based.
  - Mineral oil
  - Straight fatty oil
  - Compounded/blended oil
  - Sulphurised oil
  - Chlorinated oil

Grinding is a process carried out with a grinding wheel made up of abrasive grains for removing very fine quantities of material from the w/p surface. This can be compared to a milling process with an infinite number of cutting edges.

It is used for - M/cing materials which are too hard for other m/cing processes such as tool and die steels and hardened steel materials

- Close dimensional accuracy 0.3 to 0.5 μm
- High degree of surface smoothness. R_a = 0.15 to 1.25 μm
- roughing & finishing.

Characteristics

Abrasive Types They have the ability to facture into smaller pieces when the force increases, which is called "friability". This property gives abrasives the necessary self-sharpening capability in use.

⇒ **Aluminium Oxide (Al_2O_3)** • Natural abrasive
• Performance is inconsistent
• have impurities ← coz
• Manufactured from aluminium ore, bauxite.
• use for ~~softer and~~ steel and high-strength material

⇒ **Silicon Carbide (SiC)** • Made from silica sand & coke
• Small amount of common salt.
• use for non-ferrous, nonmetallic, hard and dense metals

⇒ **Cubic Boron Nitride (CBN)** • Laboratory product
• less reactive with materials like hardened steel, hard chill cast iron, & nickel base and cobalt based super alloys • ~~use for hard & tough tools~~

- very expensive
- very hard (knoop hardness ~ 4700 kg/mm²)

⇒ Dimond • Hard (knoop hardness ~ 8000 kg/mm²)

- used as a cutting-tool material
- very high chemical resistance
- low therma expansion
- inert towards iron
- use for die steel & tungsten carbide.

Grain Size Size of a abrasive grain or grit,

is identified by a number which is based on the sieve sized used.

- It is very from 6 to 8 (coarse size), 500 to 600 (superfine)
- ~~Stve~~ Sieve number is spesified in terms of the number of openigs per square inch Thus, larger the grain no., fine is the grain size
- Surface finish depands upon the grain size

grain size	Surface finish, μm
46	0.8
54	0.6 to 0.8
60	0.4 to 0.6
80	0.2 to 0.4

Bond keep the grains together under the action of the grinding forces

⇒ Vitrified - most commonly used.

- It is clay, mixed with flunes such as feldspar, which is harders to a glasslike substance on firing to a temp. of about 1250°C, and develops the strength.
- Strong Bond, rigid & porous
- not affected by fluids.
- Brittle & sensitive to impact.
- It is called ceramic bond.

⇒ Silicat - Sodium silicate ($NaSiO_3$) or water glass, ~~and~~ harden when heated.

- not strong as vitrified
- It is affected by dampness but less sensitive to shocks
- less in use.

⇒ Synthetic Resin or Resinoid - ~~It is these~~

- It is thermosetting resin such as phenol formaldehyde.
- good strength bond
- more elastic than vitrified
- this is not heat and chemical resistant
- used in rough grinding, parting off and high speed grinding (50 to 65 m/s)
- also use for fine finishing of roll grinding.

⇒ Rubber - Most flexible

- Made by natural or synthetic rubber
- Strength is developed by vulcanisation.
- high strength and less porous

- Bond affected by dampness and alkaline solutions
- use for cutting of wheels, regulating wheels in centerless grinding and for polishing wheels.

=) Shellac - use lees as bond.
- Use for very high finish
- applications are rolls, cutlery, cam shaft finishing.

=) Metal - Manufacture of dimond and CBN wheels.
- very high thermal conductive metal such as copper alloy or aluminium alloy.
- Strong bond.
- Powder metallurgy tenchniques are used to make the abrasive periphery.

· Grade - Show the hardness of the wheel.

Soft - A to H
Medium - I to P
Hard - Q to Z

Structure - represent the grain spacing.

Dense - 1 to 8
open - 9 to X.....

Specification of Grinding whee

150 X 10 X 12 XW A 36 L 5 V 23

- wheel dia = 150 mm
- thickness of whee = 10 mm

- Bore dia = 32mm
- W = Manufacturer's prefix to abrasive. It is optional – nature of abrasive.
- A = Type of abrassive
- 36 = Grain size
- L = Grade
- 5 = Structure
- V = Bond
- 23 = Manufacturer's reference.