JAIPUR ENGINEERING COLLEGE AND RESEARCH CENTRE

Year & Sem – Third Year & Fifth Semester
Subject – Manufacturing Technology
Unit – Second
Presented by – Ms.Palak Jindal, Assistant Professor, Mechanical Engineering Department

VISSION AND MISSION OF INSTITUTE

VISSION - To become a renowned centre of outcome based learning, and work towards academic, professional, cultural and social enrichment of the lives of individuals and communities.

MISSION –

- Focus on evaluation of learning outcomes and motivate students to inculcate research aptitude by project based learning.
- Identify, based on informed perception of Indian, regional and global needs, areas of focus and provide platform to gain knowledge and solutions.
- Offer opportunities for interaction between academia and industry.
- Develop human potential to its fullest extent so that intellectually capable and imaginatively gifted leaders can emerge in a range of professions.

VISSION AND MISSION OF DEPARTMENT

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The Mechanical Engineering Department strives to be recognized globally for outcome based technical knowledge and to produce quality human resource, who can manage the advance technologies and contribute to society.

MISSION –

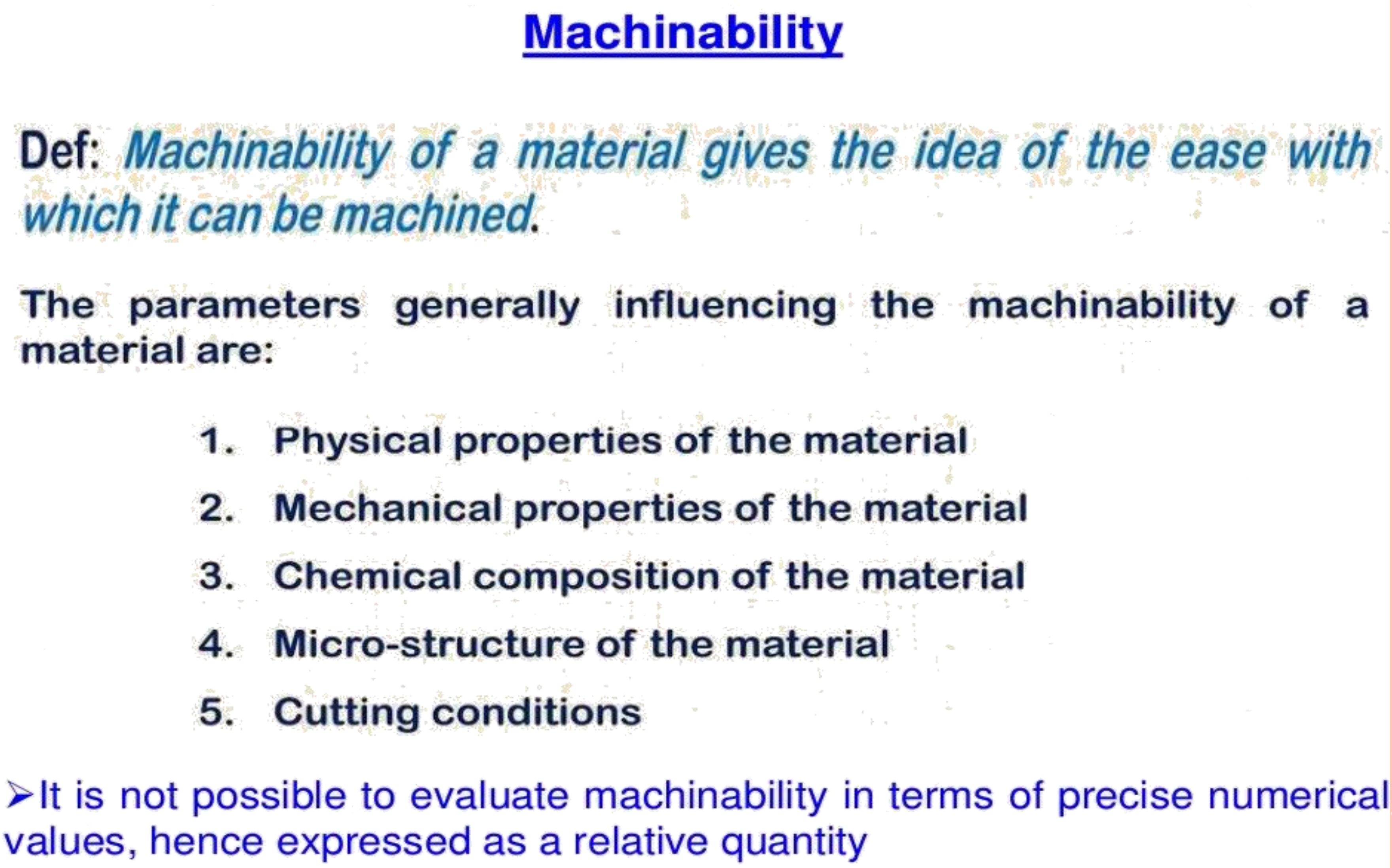
- To impart quality technical knowledge to the learners to make them globally competitive mechanical engineers.
- To provide the learners ethical guidelines along with excellent academic environment for a long productive career.
- To promote industry-institute relationship.

CONTENTS (TO BE COVERED)

RTU SYLLABUS-

Concept of machinability, machinability index, factors affecting machinability, Different mechanism of tool wear. Types of toolwear (crater, flank etc), Concept of tool life.Taylor's tool life equation. Introduction to economics of machining. Cutting fluids: Types, properties, selection andapplication methods.

- Concept of Machinability
- Machinability Index factor affecting it.
- Different Mechanism of tool wear
- Types of tool wear
- Concept of tool life
- Taylors tool life equation
- Introduction to economics of machining
- Cutting fluids



Machinability

Def: *Machinability of a material gives the idea of the ease with which it can be machined.*

The parameters generally influencing the machinability of a material are:

1. **Physical properties of the material**
2. **Mechanical properties of the material**
3. **Chemical composition of the material**
4. **Micro-structure of the material**
5. **Cutting conditions**

- It is not possible to evaluate machinability in terms of precise numerical values, hence expressed as a relative quantity

The criteria for determining the machinability are:

1. **Tool life** - The longer the tool life it enables at a given cutting speed the better is the machinability.
2. **Surface finish** – It is also directly proportional i.e., the better the surface finish the higher is the machinability.
3. **Power consumption** – Lower power consumption per unit of metal removed indicates better machinability.
4. **Cutting forces** – The lesser the amount of cutting force required for the removal of a certain volume of metal or the higher the volume of metal removed under standard cutting forces the higher will be the machinability.
5. **Shear angle** – Larger shear angle denotes better machinability.
6. **MRR** - Rate of metal removal under standard cutting conditions.

Machinability Index

- Machinability of a material is a relative quantity and machinability of different materials are compared in terms of their machinability indexes.

- **For this purpose the machinability index of *free cutting steel* serves as datum, with reference to which all other machinability indexes are compared.**

- **The machinability index of this steel is taken as *100*.**

SAE 1212 (AISI 1212)-c% 0.12 is taken as standard material for testing machinability.

$$\text{Machinability Index (\%)} = \frac{\text{Cutting speed of material for 20 min. tool life}}{\text{Cutting speed of standard free-cutting steell for 20 min. tool life}} \times 100$$

Material	Machinability Index (%)	Material	Machinability index (%)
Stainless steel	25	Red brass	180
Low carbon steel	55-65	Aluminum alloys	300-1500
Copper	70	Magnesium alloys	500-2000

Tool Wear & Tool Life

- Due to plastic deformation, heat is generated

Tool failure is observed by:

1. Extremely poor surface finish on w/p
2. Higher consumption of power
3. Work dimensions not being produced as specified
4. Over heating of cutting tool
5. Appearance of a burnishing band on the work surface

Cutting tool may fail due to one or more of the following reasons

1. Thermal cracking and softening
2. Mechanical chipping
3. Gradual wear i) Crater wear ii) Flank wear

1.Thermal cracking and softening: Due to lot of heat generated during metal cutting, the tool tip and the area closer to the cutting edge becomes very hot.

- Every tool material has a certain limit to which it can withstand the elevated temperature without losing its hardness.
- If that limit is crossed, the tool material starts deforming plastically at the tip and adjacent to the cutting edge under the action of the cutting pressure and the high temperature. Thus, the tool loses its cutting ability and is said to have failed due to softening.

1.Thermal cracking and softening Contd..

Main factors: High cutting speed, High feed rate, excessive depth of cut. Smaller nose radius and choice of a wrong tool material

Tool Material	Temp. range(°C)
Carbon tool steels	200-250
High Speed Steels(HSS)	560-600
Cemented Carbides	800-1000

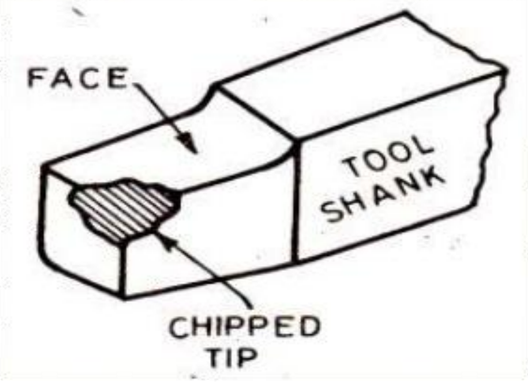
➢Because of fluctuations in temperatures, tool material is subjected to local expansion and contraction. This gives rise to the setting up of temperature stresses or thermal stresses due to which cracks are developed in the material. These are known as thermal cracks which proceed from the cutting edge and extend inwards, as shown in fig.

2.Mechanical chipping:

➢Mechanical chipping of the nose and/or the cutting edge of the tool are commonly observed causes of tool failure.

Reasons:1.Too high cutting pressure 2.Mechanical Impact 3.Excessive wear 4.Too high vibrations and chatter 5.weak tip and cutting edge

➢More pronounced in carbide tipped and diamond tools due to high brittleness of toll material



3.Gradual wear

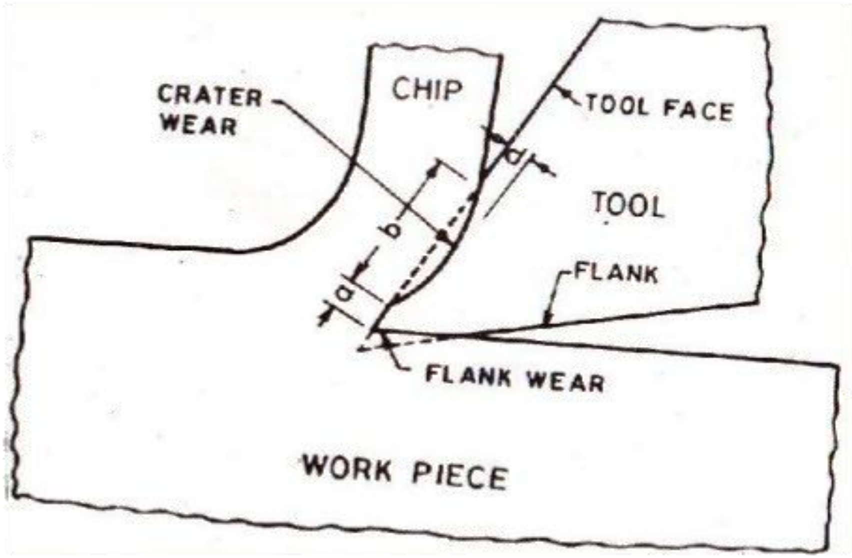
After some time of use, tool loses some weight or mass, implying that it has lost some material from it which is due to wear.

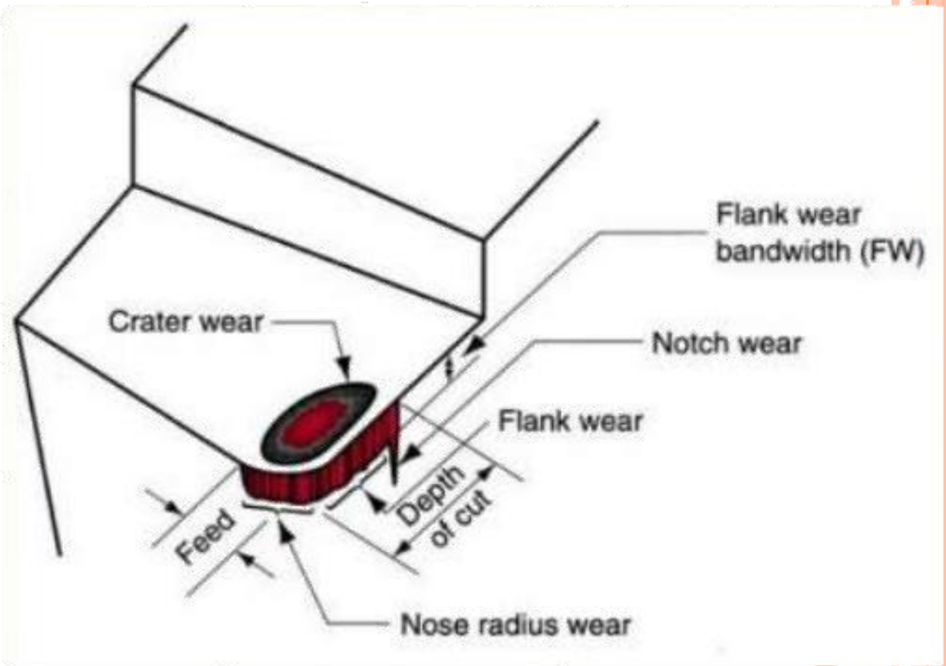
i) **Crater wear**: Occurs at tool face, at a small distance ‘a’ from its cutting edge. Occurs in ductile materials like steel and steel alloys, in which continuous chip is produced.

➢ Forms a crater or depression at the tool chip interface.

Crater wear Contd..

- Due to pressure of the hot chip sliding up the face of the tool. The metal from the tool face is supposed to be transferred to the sliding chip by means of the diffusion process.
- Size: breadth ‘b’ and depth ‘d’
- Continued growth of crater will result in weak cutting edge and finally lead to tool failure



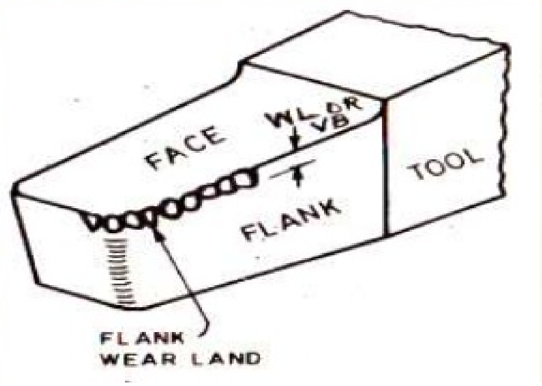


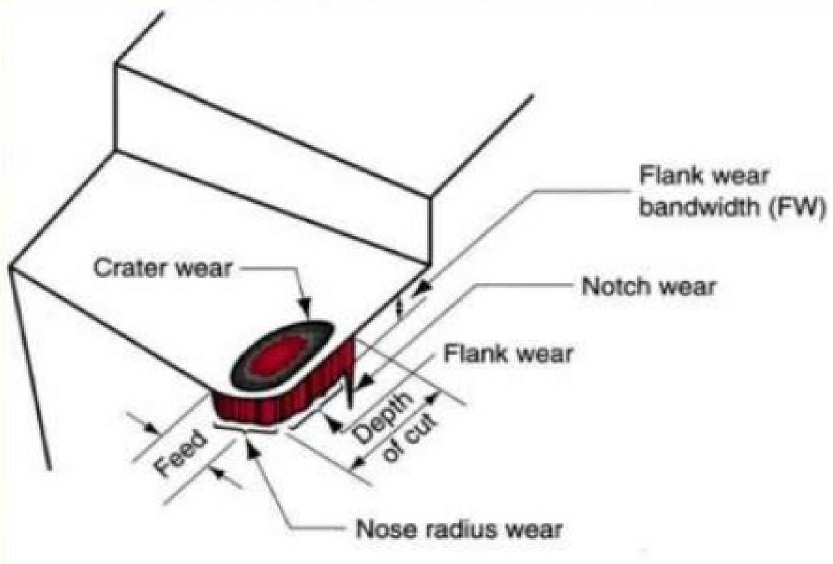
ii) **Flank wear:** At flank below the cutting edge.

- Due to abrasion between the tool flank and w/p and excessive heat generated as a result of the same.
- More pronounced while machining brittle material, because the cut chips of such materials provide a lot of abrasive material readily.
- The entire area subjected to flank wear is known as wear land(WL). This type of wear mainly occurs on the tool nose and front side relief faces as shown.
- Magnitude of this wear depends upon the relative hardness of the w/p and tool materials at the time of cutting operation

Effects:

- w/p loses its dimensional accuracy
- Energy consumption increases
- Poor surface finish





Tool life

- Tool life represents the useful life of the tool, expressed generally in time units from the start of a cut to some end point defined by failure criterion.
- A common method of forecasting tool wear is to use Taylor's equation; his study on tool life was done in 1907.
- Taylor thought that there is an optimum cutting speed for best productivity. This is reasoned from the fact that at low cutting speeds, tools have higher life but productivity is low, and at higher speeds the reverse is true.

Frederick W. Taylor
1856-1915

- This inspired him to check up the relationship of tool life and cutting speed. Based on the experimental work he proposed the formula for tool life.

Def: The time interval for which the tool works satisfactorily between two successive grindings(sharpening)

Three common ways of expressing tool life

1. Time period in minutes between two successive grindings

2. In terms of no. of components machined(C_1) between two successive grindings. This method is commonly used when the tool operates continuously, as in case of automatic machines. $Nf^aC_1^b = C$

3. In terms of volume of material removed between two successive grindings. This mode of expression is commonly used when tool is primarily used for heavy stock removal.

- Volume of material removed per unit time is a practical one and can be easily applied as

VOLUME per unit time = Velocity x area

Vol. of metal removed per minute = $\pi D N (d f)$ mm^3/min

Where D= dia. of w/p in mm

N= No. of revolutions of work per minute(rpm)

d= depth of cut in mm

f= feed rate in mm

- If 'T' be the time in minutes to tool life

total vol. of metal removed to tool failure = $\pi D N (d f) (T)$ mm^3

Factors affecting tool life:

1. Cutting speed
2. Feed & Depth of cut
3. Tool geometry
4. Tool material
5. Work material
6. Natute of cutting
7. Regidity of machine tool and work
8. Use of cutting fluids

Effect of cutting speed

-Maximum effect on tool life is of cutting speed

-Tool life varies inversely as the cutting speed, i.e higher the cutting speed, smaller the tool life

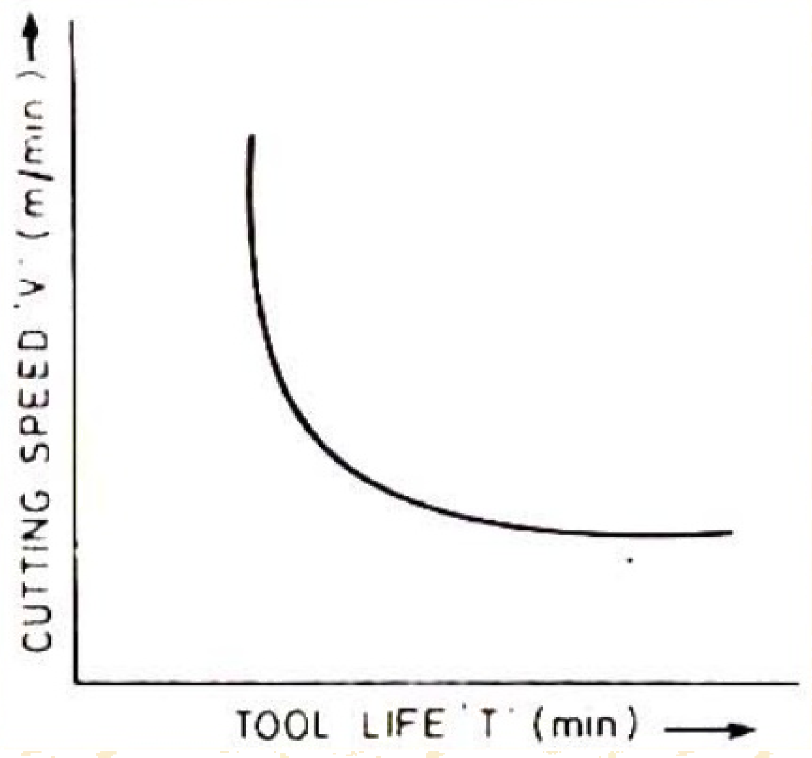
Taylor's Empirical Equation: $VT^n = C$ $V_1 T_1^n = V_2 T_2^n$

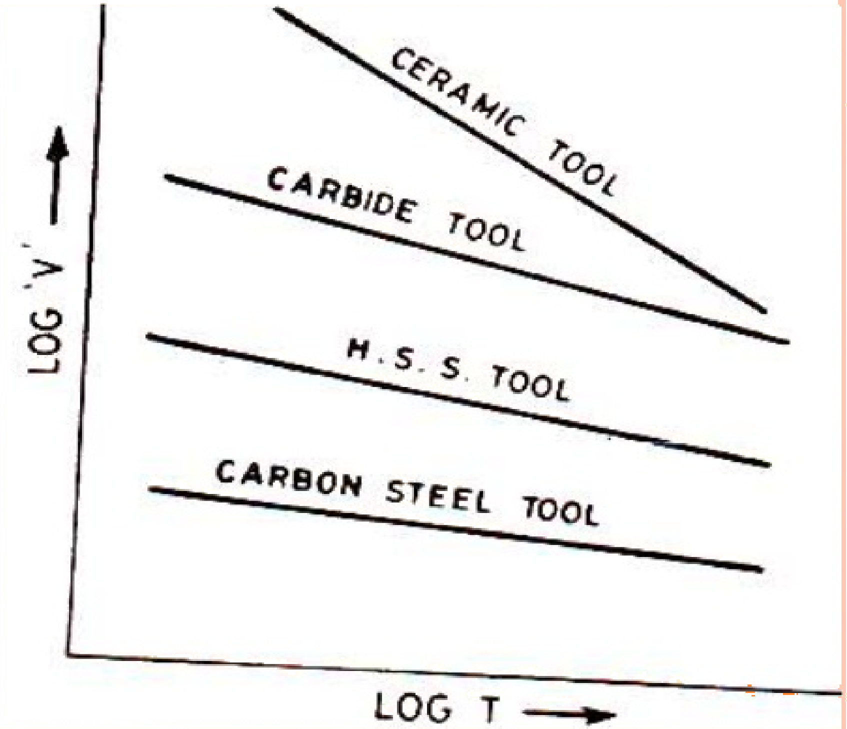
Where, T = tool lifetime; usually in minutes
V = cutting velocity, m/min
C = constant; (numerically equal to cutting speed that gives the tool life of one minute)
n = constant; which depends on finish, tool & work material, called tool life index, <1

n = An exponent, whose value depends on the tool, called tool life index or exponent. Upto a certain extent, its value is also influenced by some other variables like tool material, cutting conditions etc.

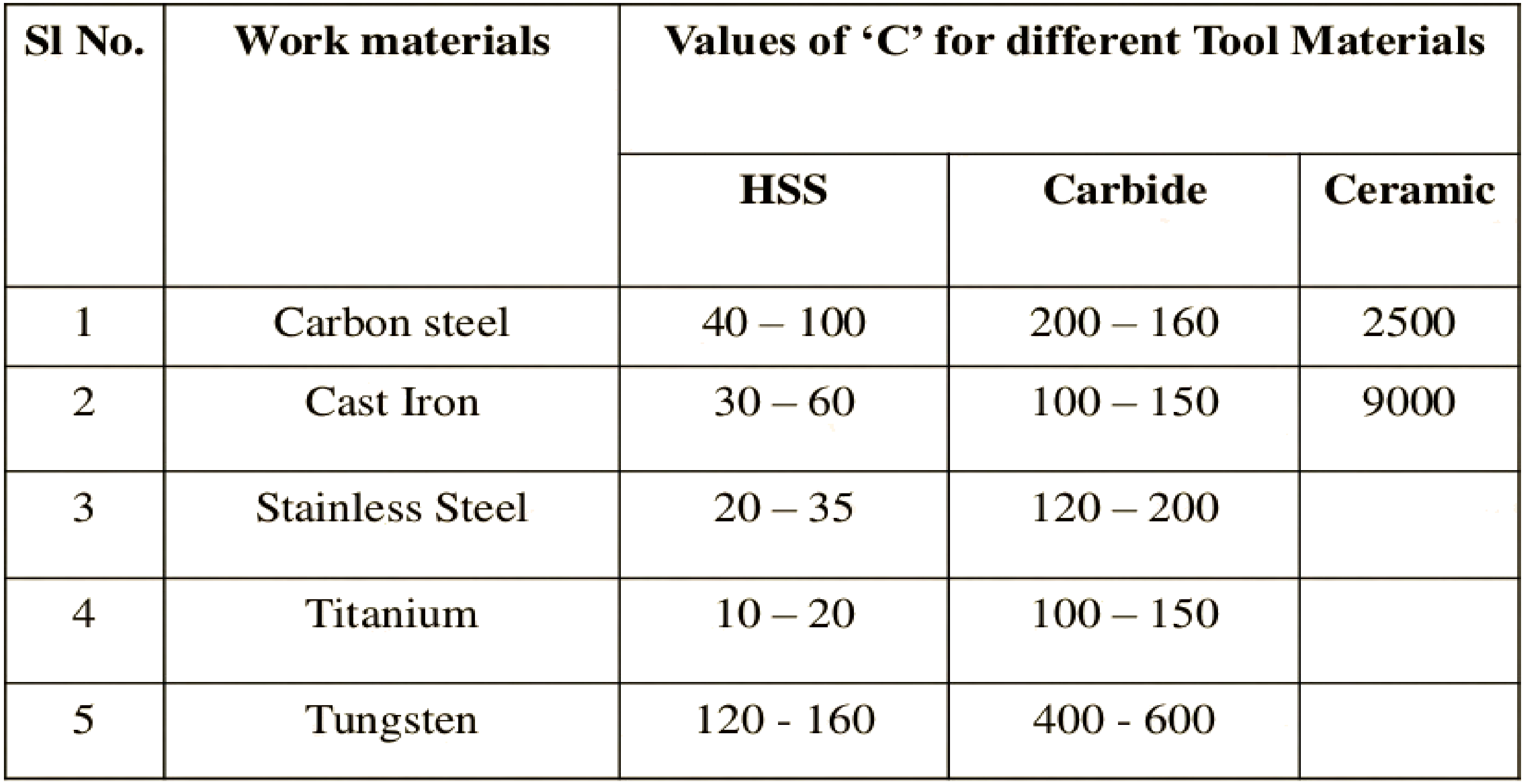
C= A constant, called machining constant, or Taylors Constant
Which is numerically equal to the cutting speed in meters per minute that would give a tool life of one minute

- Each combination of workpiece, tool material and cutting condition has its own *n* and *C* values, both of which are determined experimentally





Tool life (C and n values)



Sl No.	Work materials	Values of 'C' for different Tool Materials		
		HSS	Carbide	Ceramic
1	Carbon steel	40 – 100	200 – 160	2500
2	Cast Iron	30 – 60	100 – 150	9000
3	Stainless Steel	20 – 35	120 – 200	
4	Titanium	10 – 20	100 – 150	
5	Tungsten	120 - 160	400 - 600	

For HSS	n= 0.08-0.2
For cemented carbides	n= 0.2 - 0.6
For ceramics	n= 0.5 to 0.8

$$V \times T^n = C$$

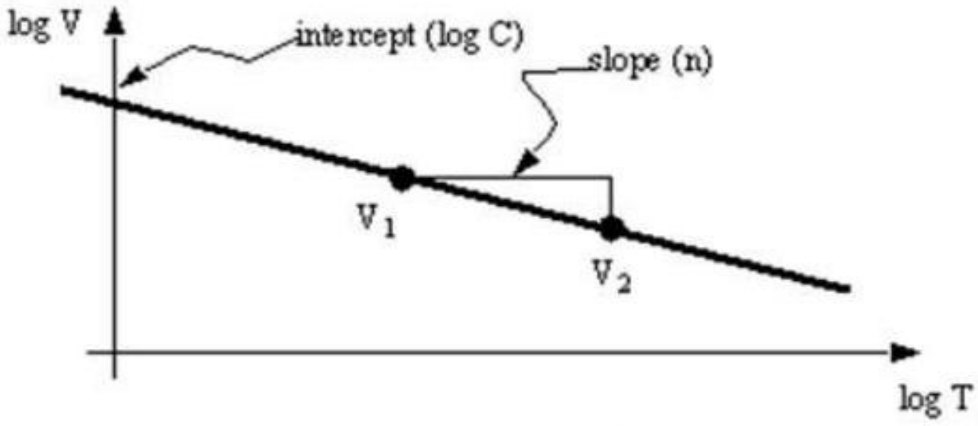
$$\therefore \log(V \times T^n) = \log C$$

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

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

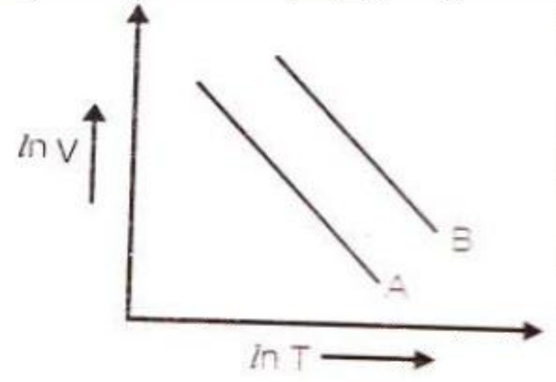
$$\therefore \log V = -n \log T + \log C$$

This function can be plotted on log scales as a linear function,



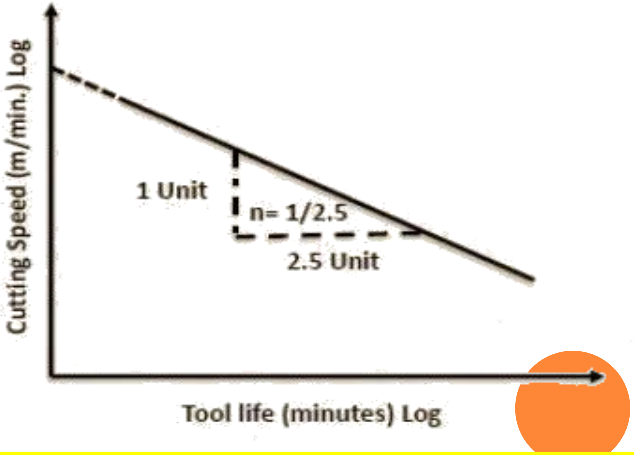
We can find the slope of the line with a two point interpolation,

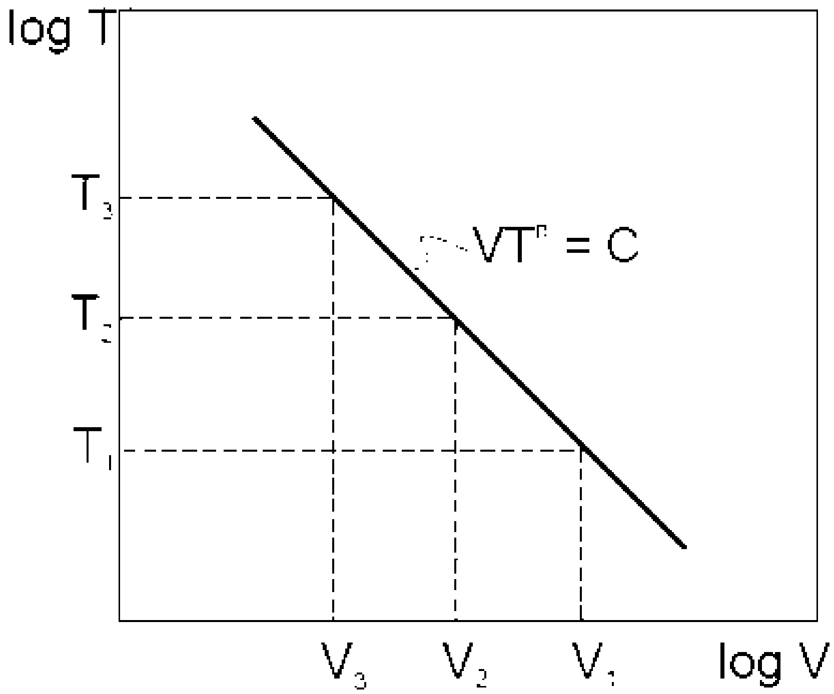
$$n = \frac{\log V_1 - \log V_2}{\log T_2 - \log T_1}$$



Two curves having same slope(n).

- B makes higher intercept on the axis.
- 'C' for B is higher than for A





$$V_1 T_1^n = V_2 T_2^n$$

- Tool life equation does not take the effective parameters such as feed(f) and depth of cut(d).

- The modified Taylor's tool life equation is **$V T^n f^x d^y = C$** or $V = \frac{C}{T^n f^x d^y}$

- For steel, x= 0.15 to 0.2 and y= 0.2 to 0.4

- By increasing the feed and depth of cut, tool life will decrease, because it increases the cutting forces.

- A General relationship between V, T, d & f is given by the empirical formula:

$$V = \frac{257}{T^{0.19} f^{0.36} d^{0.8}} m/\min$$

Where
V= cutting speed in m/min
T= Tool life in min
f = feed rate in mm/min
d = depth of cut in mm

- For a given tool life(T), the relationship among other variables is given by the empirical formula

$$V = \frac{C}{f^a d^b}$$

V= cutting sped for given tool life
C=Constant

Problem1: During turning of a 25 mm diameter steel bar on a lathe at 23.5 m/min with an HSS tool, a tool life of 10 min was observed. When the same bar was turned at 19.5 m/min, the tool life increased to 52.5 min. What will be the tool life at a speed of 22m/min

V1=23.5 m/min T1=10 min
V2=19.5 m/min T2=52.5 min
V3=22 m/min T3=?

$VT^n = C$

$V_1T_1^n = V_2 T_2^n$

$$n = \frac{\log \frac{V2}{V1}}{\log \frac{T1}{T2}} = 0.11 \qquad C = 30.27$$

$V_3T_3^n = C$

Therefore T3 = 18.2 min

2. Following data is available on cutting speed and tool life

$V=150$ m/min $T=60$ min

$V=200$ m/min $T=23$ min

Determine the Taylors constant and tool life exponent

$VT^n = C$

$150(60)^n = C$

$200(23)^n = C$

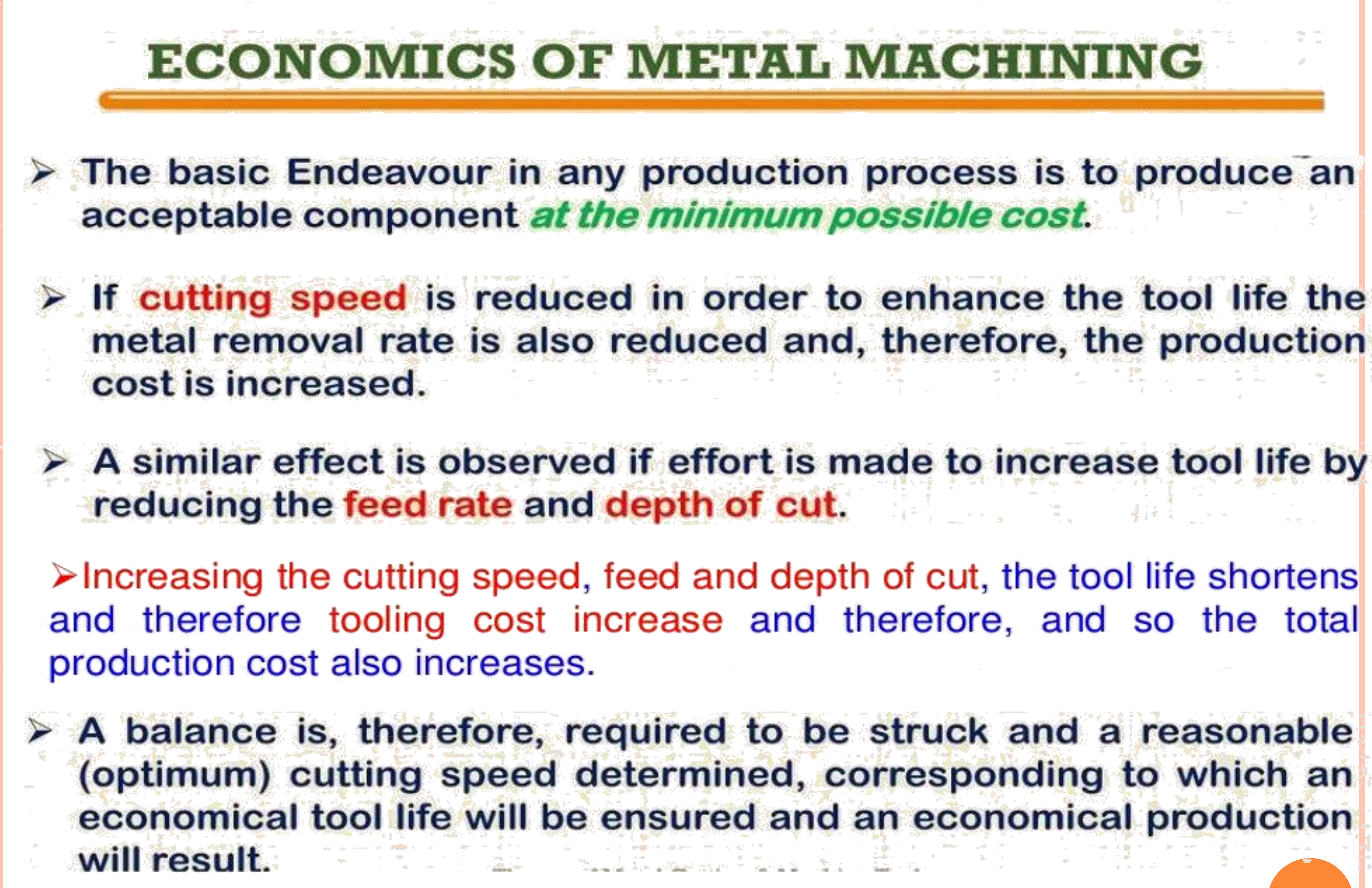
$150(60)^n = 200(23)^n$

$(60/23)^n = 200/150 = (2.6087)^n$

$n \log(2.6087) = \log 1.33$

$n = 0.3$

$C = 512.31$

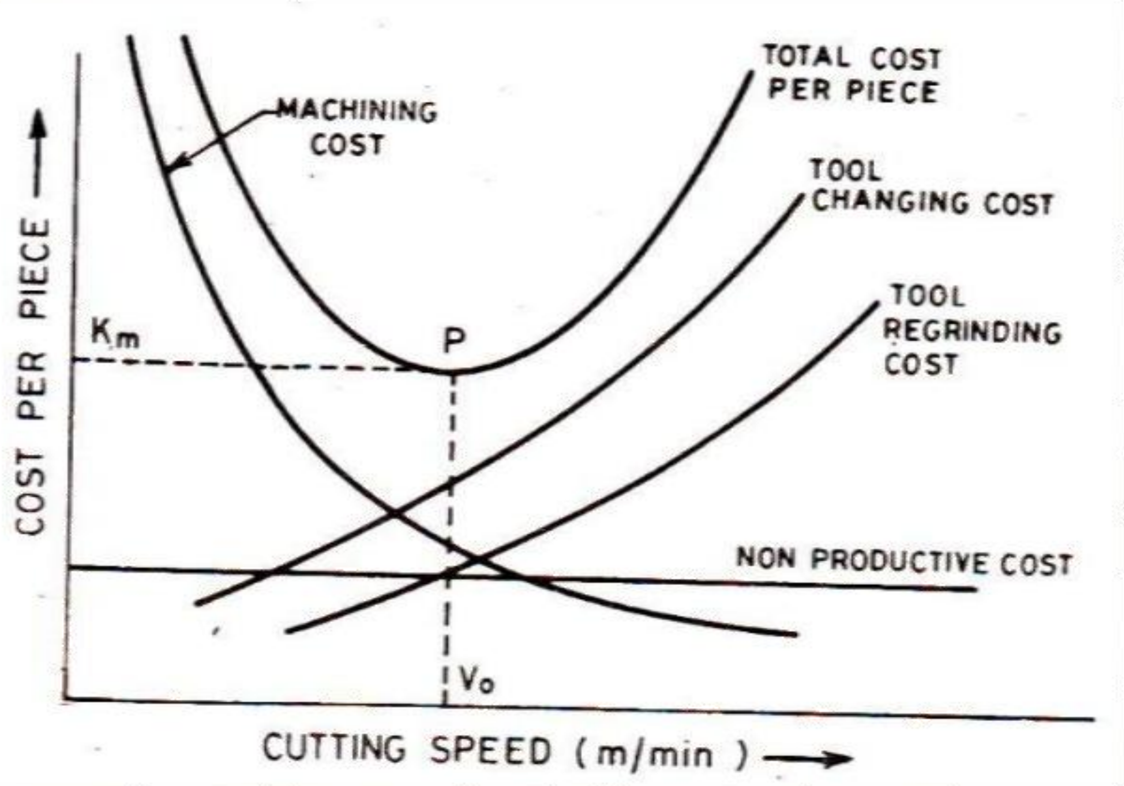


ECONOMICS OF METAL MACHINING

- The basic Endeavour in any production process is to produce an acceptable component *at the minimum possible cost*.
- If cutting speed is reduced in order to enhance the tool life the metal removal rate is also reduced and, therefore, the production cost is increased.
- A similar effect is observed if effort is made to increase tool life by reducing the feed rate and depth of cut.
- Increasing the cutting speed, feed and depth of cut, the tool life shortens and therefore tooling cost increase and therefore, and so the total production cost also increases.
- A balance is, therefore, required to be struck and a reasonable (optimum) cutting speed determined, corresponding to which an economical tool life will be ensured and an economical production will result.

1.How to find optimum cutting speed for minimum cost

- Total cost and other cost components like non productive cost (labour costs & overheads), tool regrinding, tool changing cost and machining cost are calculated and plotted for a batch of components as shown in fig.
- It is observed that tooling cost increases and machining cost decreases with increase in cutting speed



#Effect of variations in cutting speed on various cost factors

Cutting speed Vs Total cost

1. Non-productive cost(Idle cost): It is not effected by variations in cutting speed and therefore remains unchanged. (Direct labour cost + Overheads)

2. Machining cost: It reduces with increase in cutting speed

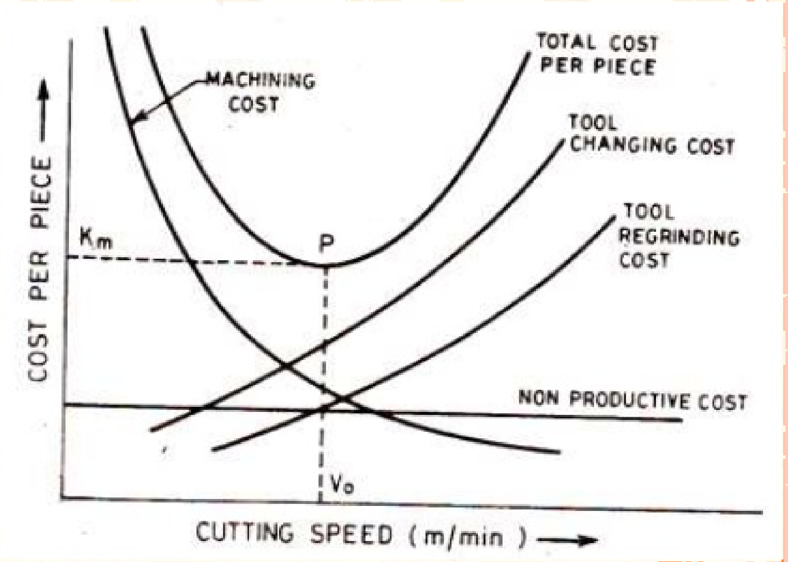
3. Tool changing cost: It increases with increase in cutting speed

4. Tool regrinding cost: This also increases with increase in cutting speed

5. Total cost: It reduces with increase in cutting speed until the latter attains its optimum value(V_0) and beyond that it increases with increase in cutting speed

At 'P' :

- Minimum cost of production. Cutting speed corresponding to this point gives the optimum cutting speed(V_0) for economical production and tool life corresponding to this optimum speed will be the most economical tool life.
- Similarly, the production cost per piece (K_m) is the minimum cost per piece.



Various costs

Material cost(R1), does not depend on cutting conditions and remains constant

1. Idle cost or Non-productive cost per piece (R2)= K_1 x T_i

K_1 = Idle cost per piece per min, in Rs/min (Labor cost + Overheads)

T_i = Idle time per piece in min

2. Cutting or Machining cost per piece(R3) =
K_1 x machining time/piece

3. Tool changing cost per piece (R4)=
K_1 x Tool failures per w/p x Tool changing time for each failure(Tc)

4. Tool regrinding cost per piece(R5) =
cost of tool per grind (K_2) x Total no. of tool failures per w/p (Tx)

K_2=cost of tool per regrind in Rs.

Let K_1 = Idle cost per piece(non productive cost) in Rs/min= Direct labour cost + Overheads

K_2=cost of tool per regrind in Rs.

T_i= Idle time per piece, in minutes

T_c=Tool changing time, in minutes

T_x = Total number of tool failures per workpiece

T_r= Tool regrinding cost per piece=K_2 x no. of tool failures per workpiece

V= Cutting speed, in m/min= $\frac{\pi DN}{1000}$

f= Feed rate, in mm/rev

D= Diameter of w/p in mm

L= Length of machining done in mm

- 1. Idle cost per piece(R2)= idle cost(Rs/min) x Idle time per piece(min) = K_1 x T_i
- 2. Cutting or Machining cost per piece (R3)= K_1 x machining time/piece

$$\text{Machining time /piece} = \frac{\text{Length of machining}}{\text{Feed rate in mm/rev x rpm}} = (T) = \frac{L}{f \times N} = \frac{\pi DL}{1000\ fV}$$

Machining time = Length/ (feed in mm/min)

Therefore, cutting cost or machining cost/piece $= K_1 \times$ Machining time/piece

$$= K_1 \times \frac{\pi DL}{1000\, fV}$$

- 3. Tool changing cost/piece (R4)=

Idle cost(K_1) x No.tool failures per w/p (T_x) x Tool changing time for each failure(T_c)

No. of tool failures per w/p(T_x) = Machining time per piece/ Tool life(T)

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

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

$$T_x = \frac{\pi DLV^{\frac{1}{n}-1}}{1000 fC^{\frac{1}{n}}}$$

So, Tool changing cost/piece (R4) $= K_1 \times \dfrac{\pi DLV^{\frac{1}{n}-1}}{1000 fC^{\frac{1}{n}}} \times T_c$

- 4. Tool regrinding cost per piece T_r (R5)

= cost of tool per grind(K_2) x No. of tool failures per w/p(T_x)

$$T_r = K_2 \times \frac{\pi D L V^{\frac{1}{n}-1}}{1000 f C^{\frac{1}{n}}}$$

Now,
total cost per piece(R) is given by
The sum of all the four cost components + material cost(R1)

R= R1+ Idle cost/piece + Machining cost/piece + Tool changing cost/piece + Tool regrinding cost/piece

$$R = R1 + K_1 \times T_i + K_1 \frac{\pi DL}{1000\ fV} + K_1 \times \frac{\pi DLV^{\frac{1}{n}-1}}{1000\ fC^{\frac{1}{n}}} \times Tc + K_2 \times \frac{\pi DLV^{\frac{1}{n}-1}}{1000\ fC^{\frac{1}{n}}} \quad \text{Rupees}$$

For minimum cost : $\frac{\partial R}{\partial V} = 0$

$$= \frac{-K_1 \pi DLV^{-2}}{f} + \frac{K_1 T_c \pi DL}{fC^{\frac{1}{n}}}\left(\frac{1}{n}-1\right)\left(V^{\frac{1}{n}-2}\right) + \frac{\pi DLK_2}{fC^{\frac{1}{n}}}\left(\frac{1}{n}-1\right)\left(V^{\frac{1}{n}-2}\right) = 0$$

On simplification

Cutting speed $$V_{0pt} = \frac{C}{\left[\left(\frac{1}{n}-1\right)\left(\frac{K_1T_c+K_2}{K_1}\right)\right]^n}$$

Tool life (T_{mc}) = $$\left(\frac{1}{n}-1\right)\left(\frac{K_1T_c+K_2}{K_1}\right)$$

Cutting Fluids

- **Cutting fluids are used for decreasing power requirement and increasing heat dissipation.**

- New materials, changes in equipment design has led to faster machining speeds and higher cutting temperatures to help improve productivity

- High forces (345 MPa) & Temperatures (900 ^{0}C) can be generated at work tool interface

Cutting fluids generally used are

1.Neat oils(mineral) + Extreme pressure additives(EP additives)

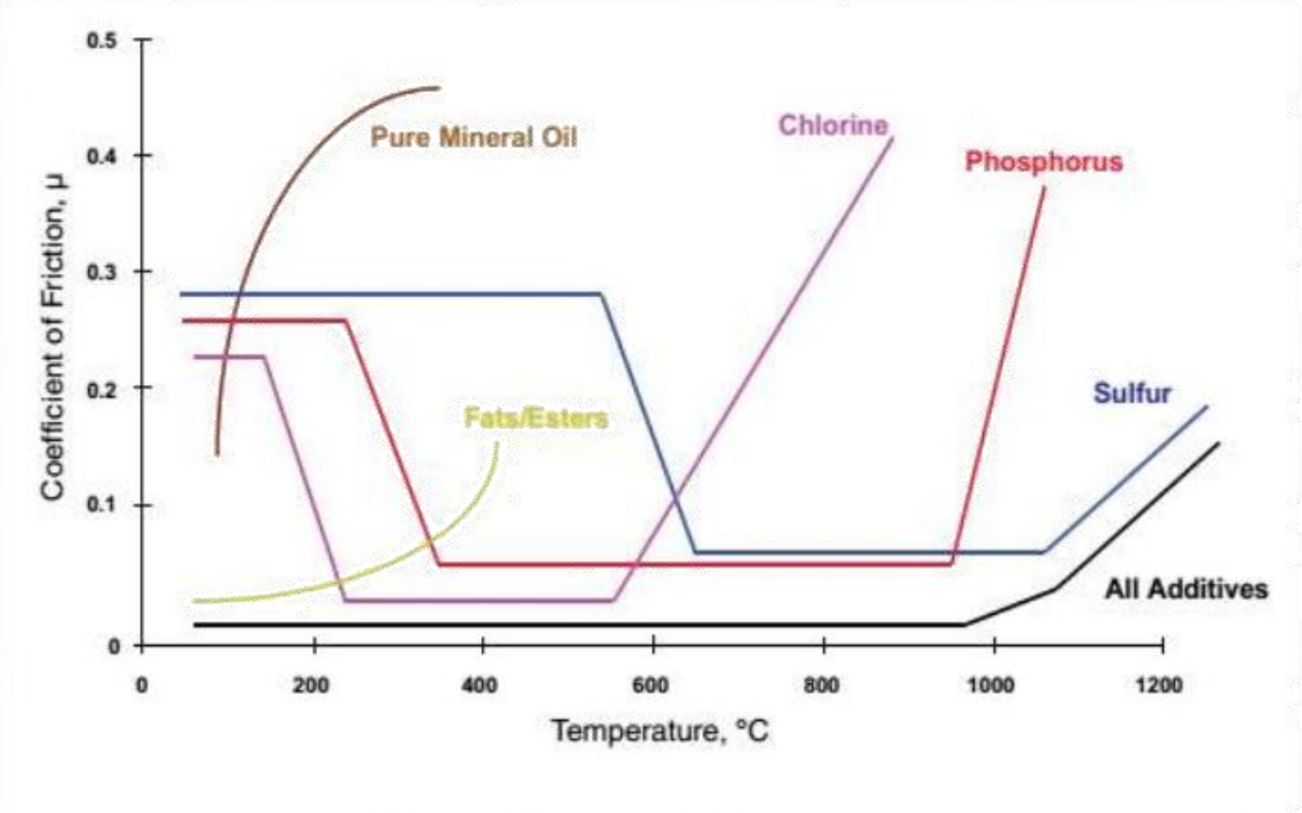
2.Water based fluids (soluble oils or emulsions(immiscible))
Oil to water ratio between 1:5 to 1:50 for machining and
upto 1:80 for grinding

Base oils:mineral(neat), synthetic, vegetable and animal

- Extreme pressure (EP) additives prevent seizure conditions caused by direct metal-to-metal contact between the parts under high loads.

- Chlorinated paraffins, phosphorous compounds, sulphurized additives, polymeric esters are typical Extreme Pressure additives, which are added into neat oils

Cumulative effects of additive chemistries



- ➢Short and medium chain chlorinated paraffins are considered carcinogenic, toxic to marine life and will not be authorized to be used in products that will affect health and environment

- ➢Use of chlorinated paraffins will cause detrimental effect on the environment because, use and disposal of chlorinated cutting fluids have low solubility in water and environment persistence.

➢For many years metal removing industry has used neat oils that contain chlorine. Ongoing changes in machine tool design and global health and environmental related concerns are limiting their use and leading to new opportunities for non-chlorinated products.

Neat cutting oils are fluids usually based on mineral oils and used for cutting without further dilution i.e. as supplied by the manufacturer. They are generally blends of mineral oils and other additives.

Properties of Cutting fluids

1. High thermal conductivity
2. Low viscosity
3. It should not react with machining components
4. Easily available
5. It should not fume
6. It should not foam
7. It should not give bad odour

1.Water
2.Straight oils (neat oil + EP)
3.Soluble oils & Emulsions (water based cutting fluids, Mineral oil + Emulsifier)
4.Synthetic fluids (no petroleum or mineral oils)
5.Semisynthetic fluids(Synthetic & soluble oils)

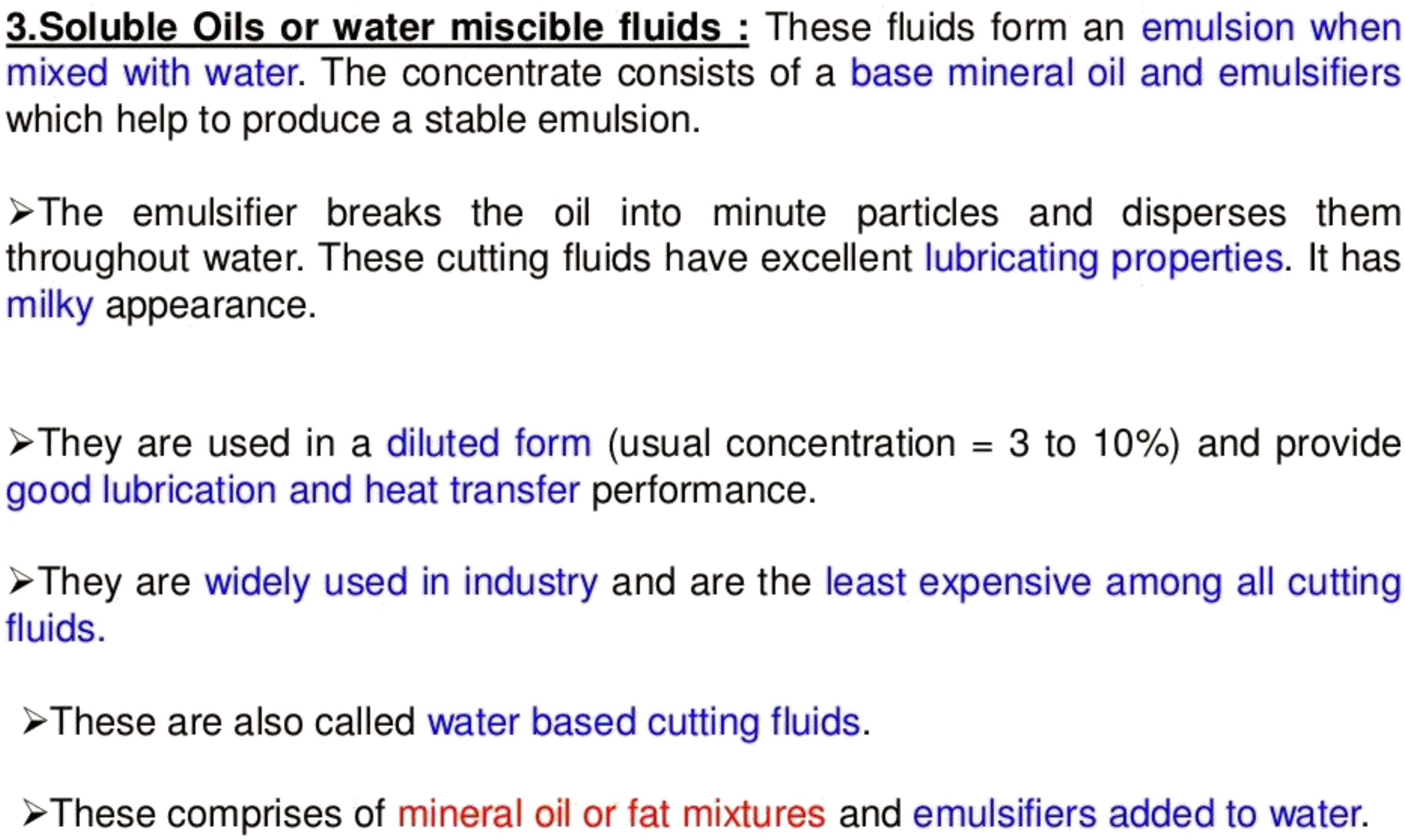
1.Water: Water provided good cooling effect but is not a good lubricant. Water is hardly used as cutting fluid because of its corrosiveness.

2.Straight oils: are used in machining operations in an undiluted form. They are composed of a base mineral or petroleum oil and often contains lubricants such as fats, vegetable oils and esters as well as extreme pressure additives such as Chlorine, Sulphur and Phosphorus.

Straight oils provide the best lubrication and the poorest cooling characteristics among cutting fluids

- Suitable only for low cutting speed. These are of three types:
  1.Mineral oil: Kerosene, low viscosity petroleum fraction.
  2.Fatty oil: Lard oil (Animal oil like pig)
  3.Combination of mineral and fatty oil

- Addition of sulphur or chlorine compounds(with EP) reduces chances of chip welding on the tool rake face. Also to improve corrosion protection.



3.Soluble Oils or water miscible fluids : These fluids form an emulsion when mixed with water. The concentrate consists of a base mineral oil and emulsifiers which help to produce a stable emulsion.

- The emulsifier breaks the oil into minute particles and disperses them throughout water. These cutting fluids have excellent lubricating properties. It has milky appearance.
- They are used in a diluted form (usual concentration = 3 to 10%) and provide good lubrication and heat transfer performance.
- They are widely used in industry and are the least expensive among all cutting fluids.
- These are also called water based cutting fluids.
- These comprises of mineral oil or fat mixtures and emulsifiers added to water.

4.Synthetic Fluids contain no petroleum or mineral oil base and instead are formulated from inorganic and organic compounds along with additives for corrosion inhibition.

➢They are generally used in a diluted form (usual concentration = 3 to 10%).

➢Synthetic fluids often provide the best cooling performance among all cutting fluids.

Synthetic lubricants can be manufactured using chemically modified petroleum components rather than whole crude oil, but can also be synthesized from other raw materials.

it provides superior mechanical and chemical properties to those found in traditional mineral oils

5.Semi-synthetic fluids are essentially combination of synthetic and soluble oil fluids and have characteristics common to both types.

- The cost and heat transfer performance of semi-synthetic fluids lie between those of synthetic and soluble oil fluids.

Cutting tool material

HSS: Need to be cooled as they lose their hardness at high temp (above 600^{0}C)

Carbide tipped tools: Do not require any cutting fluid as they retain hardness at high temp.

Workpiece material

- ➢Hard and brittle materials such as cast iron(1.8-4.5% carbon) and brass are usually machined dry.
- ➢Soft materials such as mild steel & wrought iron need cutting fluids with good cooling capacity and antiwelding properties

Material	Cutting fluids
Aluminium	Kerosene, soluble oil
Brass	Dry machining(paraffin oil may be used)
Cast Iron	Dry machining(compressed air may be used to blow away the chips)
Malleable CI	Dry machining or soluble oil
Wrought Iron	Soluble oils, sulphurised oil, Lard oil
Steel	Soluble oils, Sulphurised oil, Mineral oil

Cast Iron: Cutting fluids are not used because, it produces graphite flakes, this mixes with the cutting fluid and affects the machining area. So either no cutting fluid is used or compressed air is used

Steel: For low cutting speeds, neat oil and EP additives are used. For medium cutting speeds, water emulsions in the ratio of 1:10. For high cutting speeds water emulsions in the ratio 1:100

Aluminium: Very soft material. At high speed nothing is required. But at low speed, there will be a tendency of build up edge formation, so neat oils(Kerosene) with EP additives are used

Magnesium: Reacts with water at high temperatures and burns. So only neat oils are used

Brass and Bronze: EP additives present in the cutting fluid reacts with the material and produces dull surface. So only neat oils like kerosene is used

Dry Machining

➢With the continued development of advanced tool coatings, high-speed dry machining of cast iron has become possible.

➢Heat dissipation without coolant requires high-performance tool coatings, heat-resistant tool materials and high pressure through spindle air.

For high-speed dry machining of cast iron, the tools must have:

- high hardness at high operating temperatures to resist abrasive wear;
- high structural strength to resist cutting forces at high chip loads and high operating temperatures;
- high fracture toughness, resistance to thermal shocks and chemical stability with respect to the workpiece.

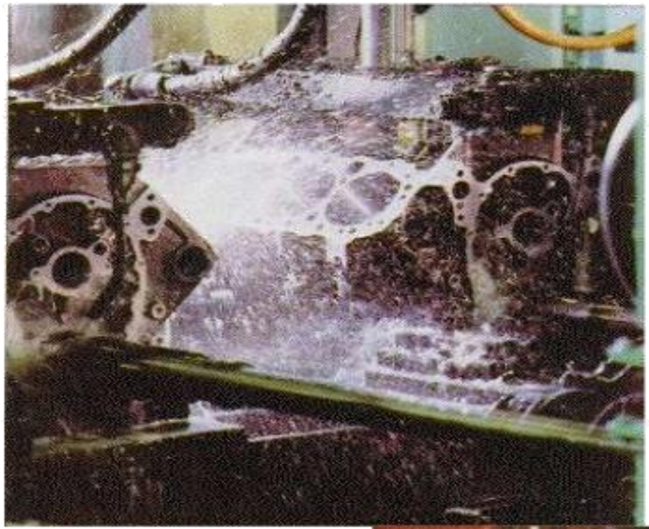
➢Dry machining requires either coated tools or ceramic/cubic boron nitride cutting tool materials to withstand the intense heat generated by the process.

➢The coatings with a low friction coefficient and low thermal conductivity work best at isolating a tool from heat and TiAlN-based coatings are recommended for dry machining of cast ferrous materials, including cast irons.

Methods of Application of cutting fluids:

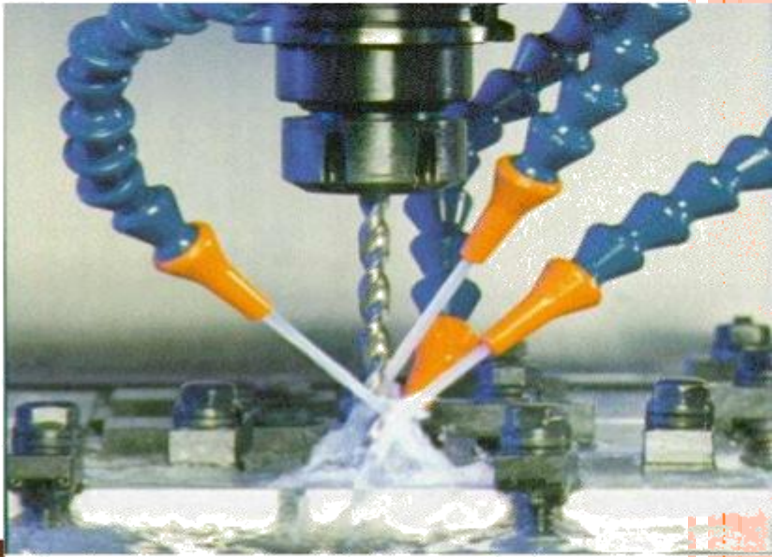
Hand applications: use of brush or oil-can to high pressure applications

For high production: 1.Flood method 2.Jet Method 3. Mist methods



1.Flood

2.Jet



3.Mist :cutting fluid is atomised by a jet of air and the mist is directed at the cutting zone

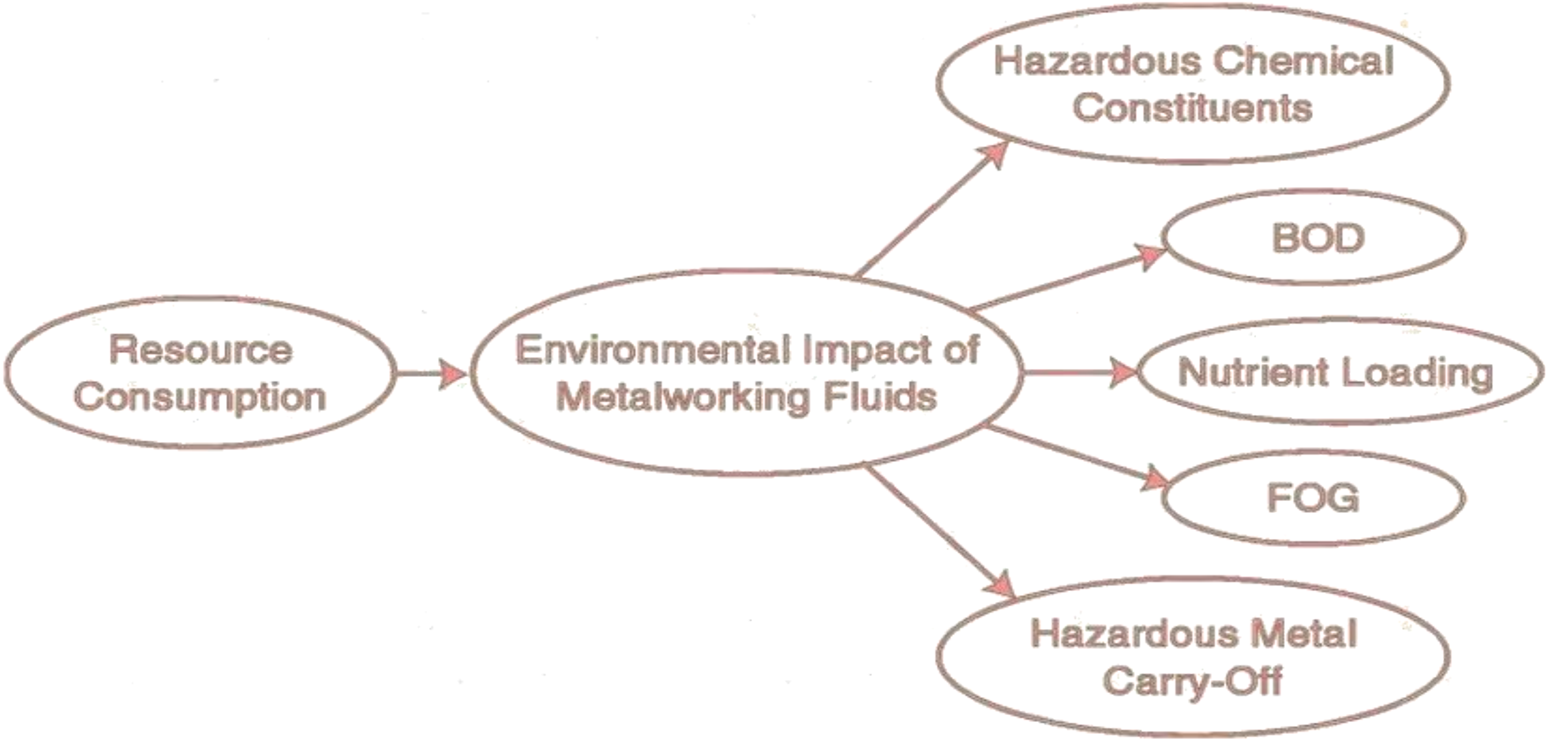
4.2 Cutting Fluids

- Enhances the machining quality while reducing the cost of machining.
- A large variety of cutting fluids based on organic and inorganic materials have been developed.

4.2 Cutting Fluids

- The mist and vapor generated is harmful for the operator.
- Direct exposure of cutting fluids has been responsible for a number of skin cancer cases.
- Recycled or disposed of in a manner that is not harmful to the environment.

Concerns Associated with Metal Working Fluid(MDF) Use



Resource Consumption

Environmental Impact of Metalworking Fluids

Hazardous Chemical Constituents

BOD

Nutrient Loading

FOG

Hazardous Metal Carry-Off

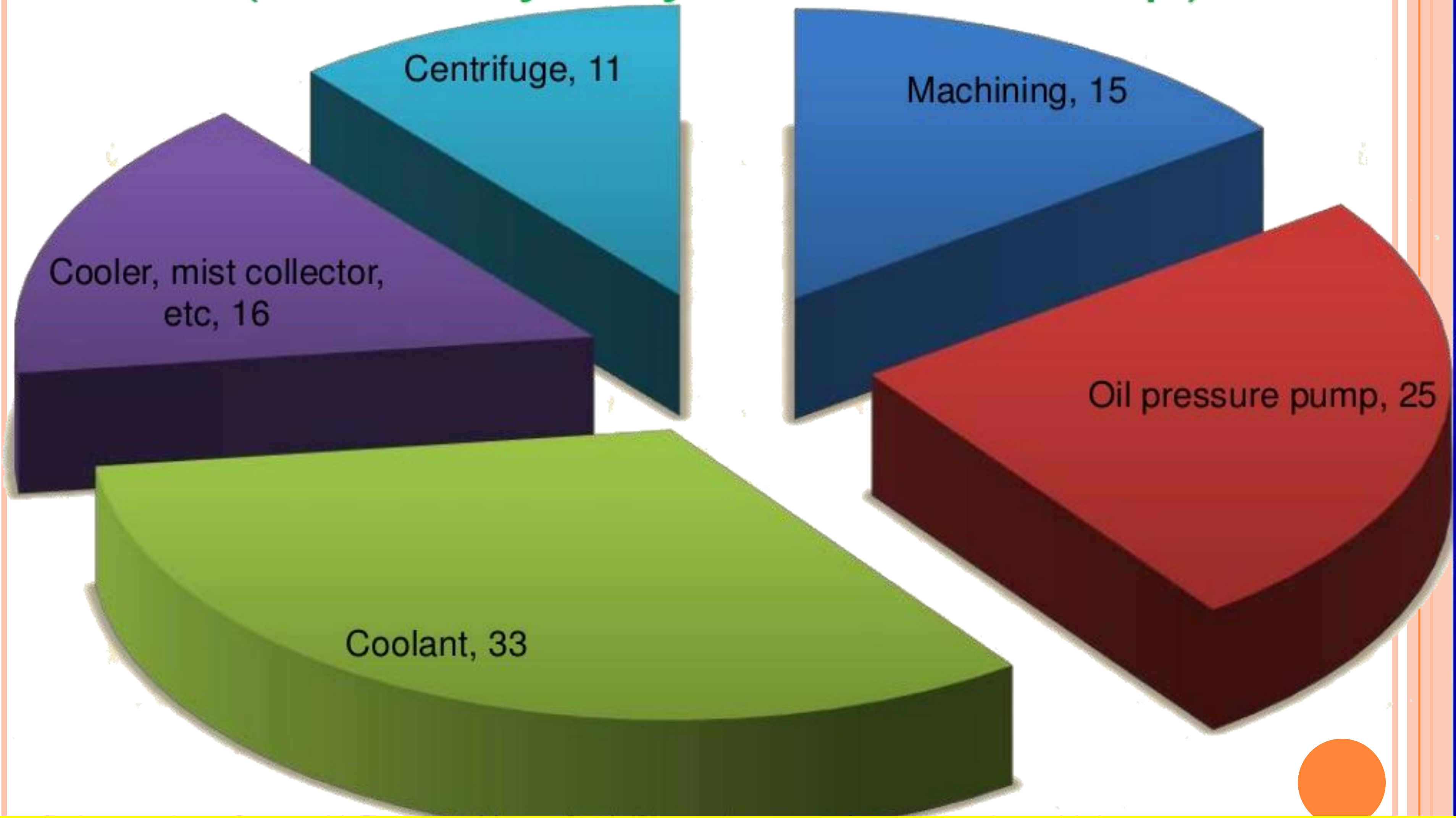
BOD-Biochemical oxygen demand

FOG- Fats Oils & Grease

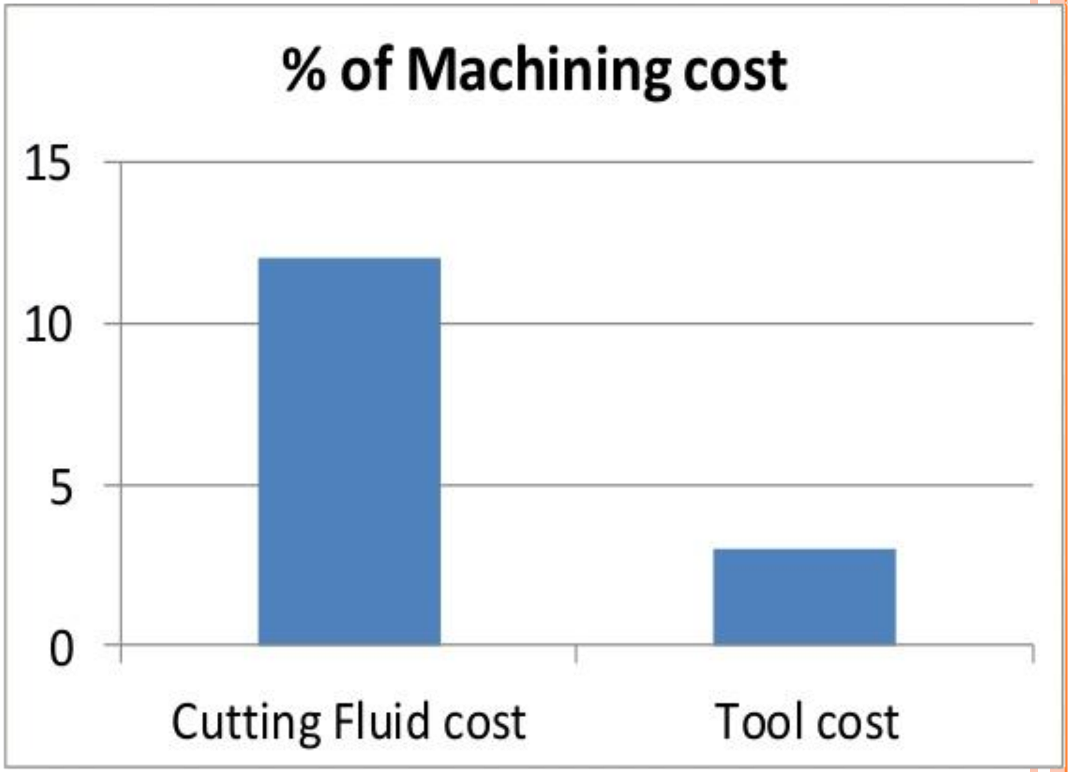
Cutting Fluid

- Coolant consumption is estimated higher than 100 million gallons per year in U.S (c 1996).
- U.S. consumed 2 billion gallons in 2000.
- The cost of purchasing and disposing cutting fluid is about 48 billion dollars a year
- Why such large costs?
  - Purchase: $5-$16/gallon concentrate
  - Maintenance:$0.20-$1.20/gallon
  - Disposal: $0.25-$2/gallon

Energy breakdown % for Machining (Courtesy Toyota Motor Corp)



Cutting Fluid



- Cutting fluids cost 7-17% of the manufacturing cost in German automotive industry compared to tool costs that are quoted as being 2 – 4%.

Cutting Fluid

- Use dry cutting
- Minimum Quantity Lubrication (MQL)
  - Drop lets (without compressed air)
  - Mist with compressed air
- Vegetable based cutting fluids
- Use nano cutting fluids
- Use nano coated tools in drycutting

TOOL MATERIAL

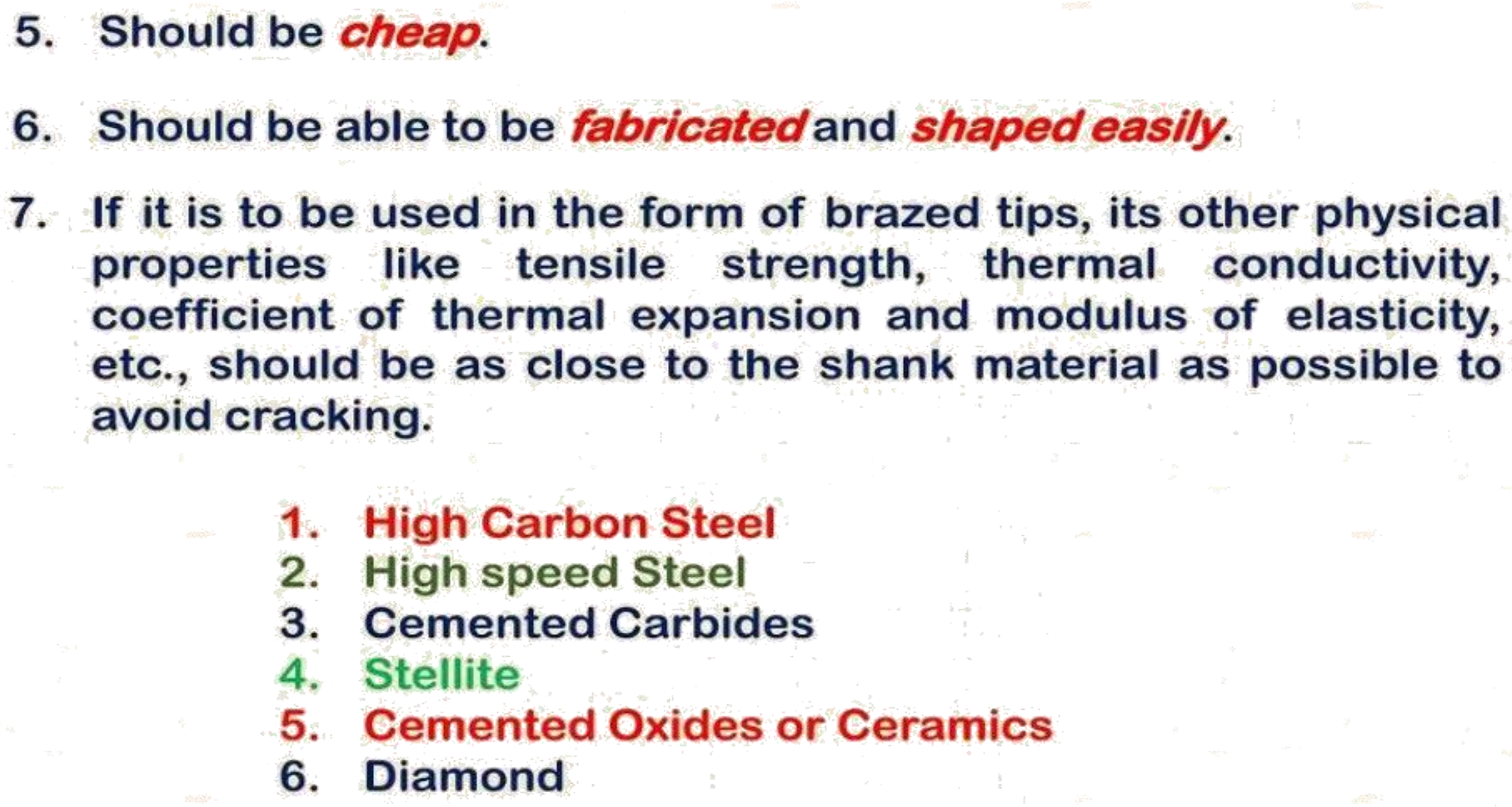
The main characteristics of a good cutting tool material are its hot hardness, wear resistance, impact resistance, abrasion resistance, heat conductivity, strength, etc.

An ideal tool material is the one which will remove the largest volume of work material at all speeds

Higher the hot hardness and toughness in the tool material, the longer the tool life

The material used for the manufacture of cutting tools should posses the following characteristics:

1. Ability to retain its hardness at elevated temperatures, called ***hot hardness***.
2. Ability to resist shock, called ***toughness***.
3. High ***resistance to wear***, to ensure longer tool life.
4. Low ***coefficient of friction***, at the chip-tool interface, so that the surface finish is good and wear is minimum.



5. Should be *cheap*.

6. Should be able to be *fabricated* and *shaped easily*.

7. If it is to be used in the form of brazed tips, its other physical properties like tensile strength, thermal conductivity, coefficient of thermal expansion and modulus of elasticity, etc., should be as close to the shank material as possible to avoid cracking.

1. High Carbon Steel
2. High speed Steel
3. Cemented Carbides
4. Stellite
5. Cemented Oxides or Ceramics
6. Diamond

7. CBN

8.Cermet

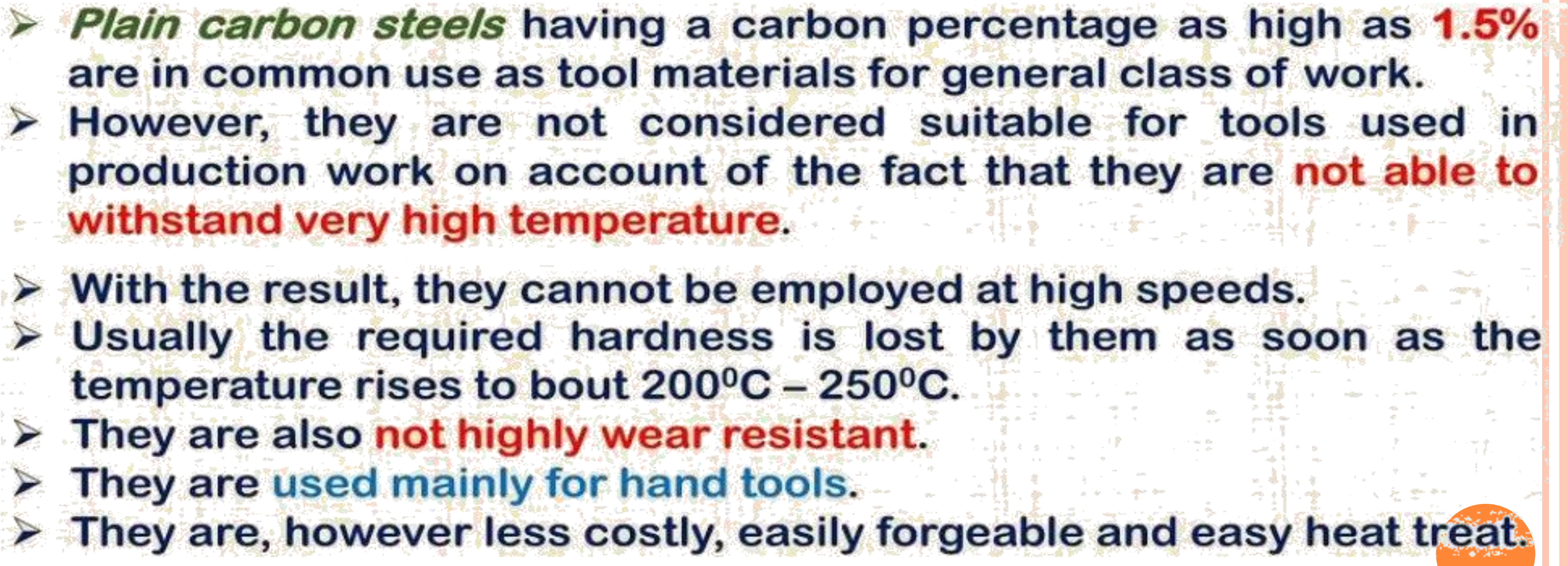
High Carbon Steel

Low alloy steels

- High carbon tool steel is the oldest cutting tool materials, having C content ranging from 0.7 – 1.5% carbon.

- Shaped easily in the annealed condition and subsequently hardened by quenching and tempering. • Hv ~ 700 after quenching and tempering.

➢ **For low cutting speed due to a drop in hardness above 150°C.**



➢ ***Plain carbon steels*** **having a carbon percentage as high as 1.5% are in common use as tool materials for general class of work.**

➢ **However, they are not considered suitable for tools used in production work on account of the fact that they are not able to withstand very high temperature.**

➢ **With the result, they cannot be employed at high speeds.**

➢ **Usually the required hardness is lost by them as soon as the temperature rises to bout 200°C – 250°C.**

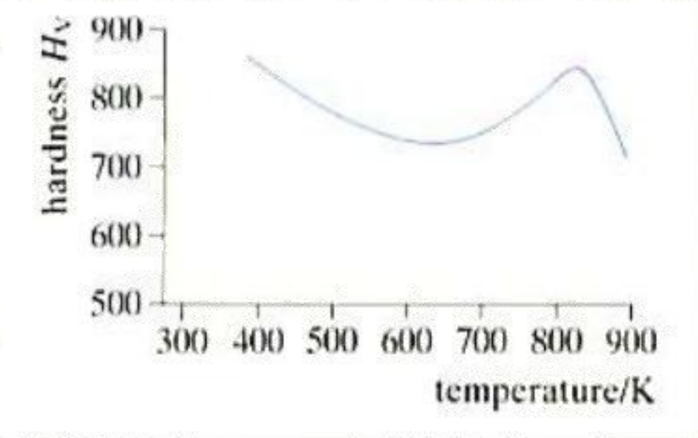
➢ **They are also not highly wear resistant.**

➢ **They are used mainly for hand tools.**

➢ **They are, however less costly, easily forgeable and easy heat treat.**

High speed steels (HSS)

- Retain their *hot hardness* up to 500°C.
- *Cutting speed* ~ 2 times higher than carbon tool steels.
- Very stable secondary carbide dispersions (between 500-650°C), giving rise to a tempering curves.



- *Carbon content* in each steel is balanced against the major alloying elements to form the appropriate stable mix of carbides with ***W***, ***Mo***, ***Cr*** and ***V***.
- *Cobalt* is added to slow down the rate of carbide coarsening → material can withstand higher temperatures.
- *M series* have higher abrasive resistance and cheaper.
- Cannot stand very high speed cutting.

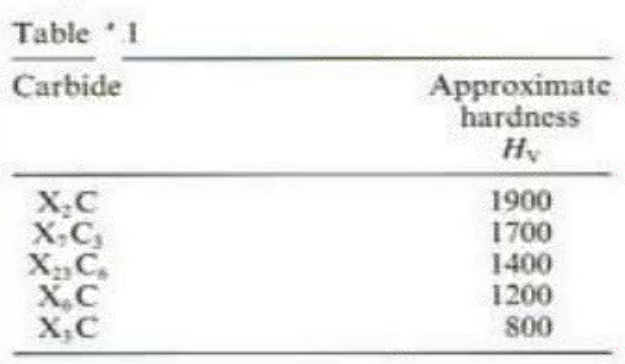


Table *1

Carbide	Approximate hardness H_V
X_2C	1900
X_7C_3	1700
$X_{23}C_6$	1400
X_6C	1200
X_3C	800

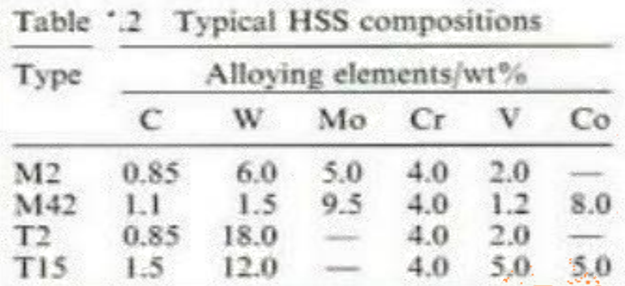


Table *2 Typical HSS compositions

Type	Alloying elements/wt%					
	C	W	Mo	Cr	V	Co
M2	0.85	6.0	5.0	4.0	2.0	—
M42	1.1	1.5	9.5	4.0	1.2	8.0
T2	0.85	18.0	—	4.0	2.0	—
T15	1.5	12.0	—	4.0	5.0	5.0

High Speed Steel (HSS)

- It is a special alloy-steel which may contain the alloying elements like tungsten, chromium, vanadium, cobalt and molybdenum, etc., up to 25 percent.

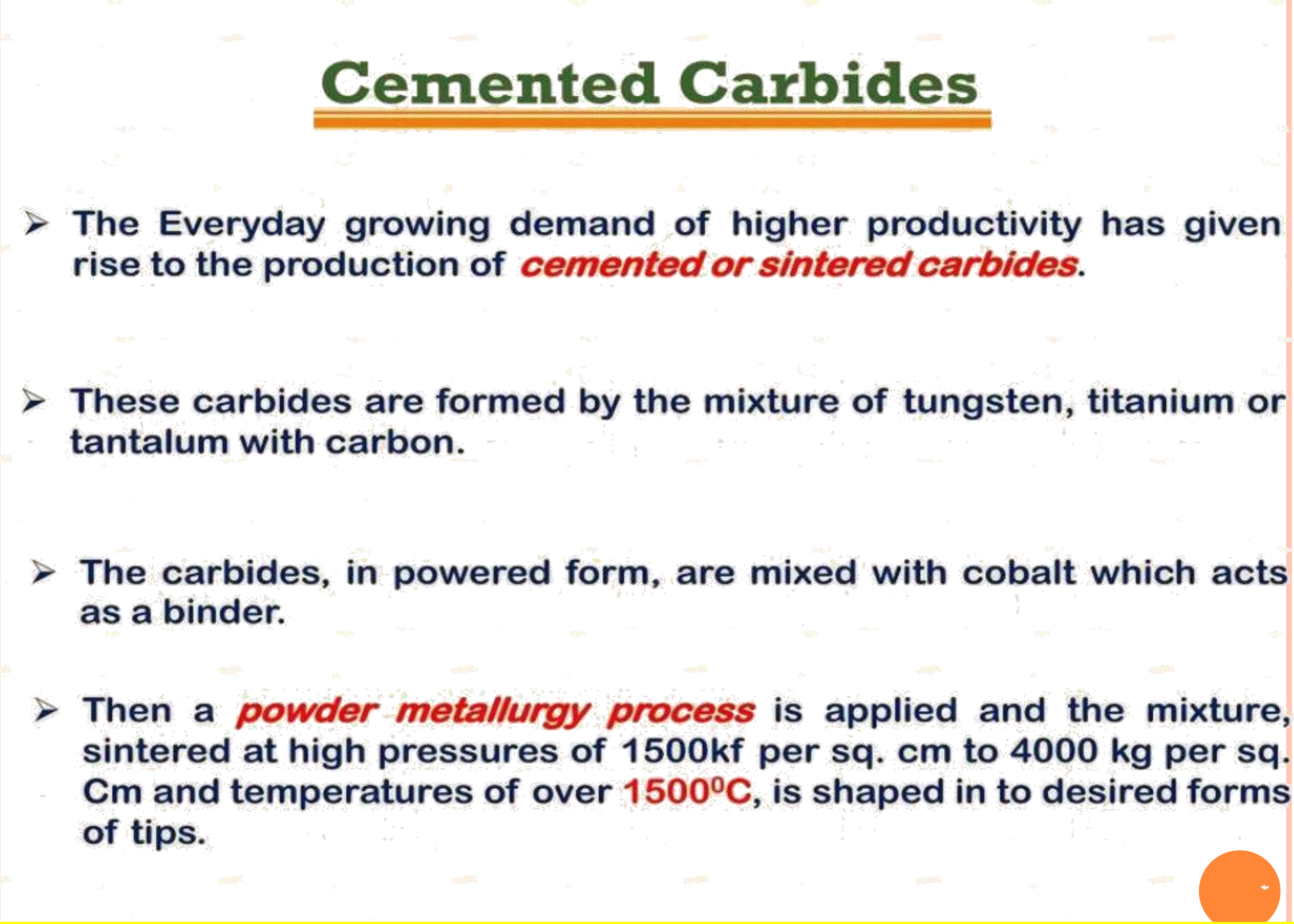
- These alloying elements increase its strength, toughness, wear resistance, cutting ability to retain its hardness at elevated temperatures in the range of 550^{0}C to 600^{0}C.

- On account of these added properties the high speed steel tools are capable of operating safely at 2 to 3 times higher cutting speeds than those of high carbon steel tools.

- The most commonly used high speed steel is better known by its composition of alloying elements as *18-4*-1 i.e, the one that contains 18%W ,4% Cr and 1% V.

- Another class of H.S.S. contains high proportions of cobalt (2 to 15%) and is known as cobalt H.S.S.

- It is highly wear resistance and carries high hot hardness.



Cemented Carbides

- The Everyday growing demand of higher productivity has given rise to the production of *cemented or sintered carbides*.

- These carbides are formed by the mixture of tungsten, titanium or tantalum with carbon.

- The carbides, in powered form, are mixed with cobalt which acts as a binder.

- Then a *powder metallurgy process* is applied and the mixture, sintered at high pressures of 1500kf per sq. cm to 4000 kg per sq. Cm and temperatures of over 1500^0C, is shaped in to desired forms of tips.

- These carbide tips are then brazed or fastened mechanically (clamped) to the shank made of medium carbon steel.

- This provides an excellent combination of an extra-hard cutting edge with a tough shank of the tool.

- These cemented carbides posses a very high degree of hardness and wear resistance.

- Probably diamond is the only material which is harder than these carbides.

- They are able to retain this hardness at elevated temperatures up to 1000^0C.

- With the result, the tools tipped with cemented carbide tips are capable of operating at speeds 5 to 6 times (or more) higher than those with the high speed steels.

- It will be interesting to note at this stage that the best results with these tools can be obtained only when the machines, on which they are to be used, are of rigid construction and carry high powered motor so that higher cutting speeds can be employed.

Cemented carbides

- Consist of ***heat-resistant refractory carbides*** (hardness) embedded in a ductile metal matrix (toughness).

Cemented carbides fastened to the tool post.

- Normally made by ***powder processing*** using liquid phase sintering.
- Has advantage over high speed steel in that the obtained **carbides** are much more stable, see *Table*.
- They are ***brittle*** so should run without vibration or chatter.
- ***Cobalt*** is used as a binder.

- **Cutting temperature** up to 1100°C.
- **Cutting speed** ~ 5x that used with high speed steel.

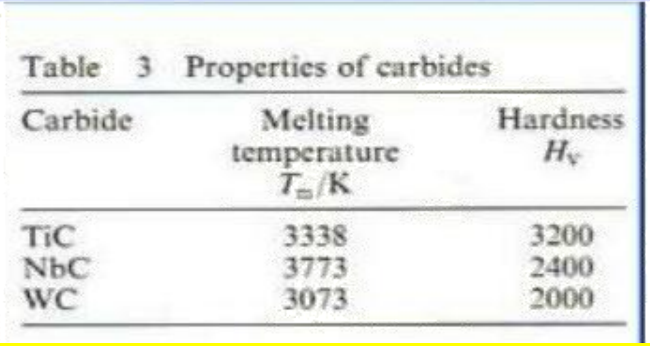
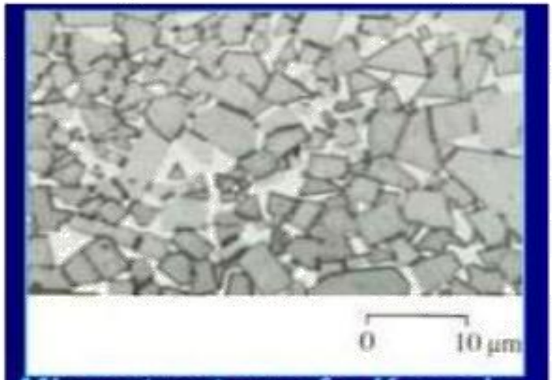


Table 3 Properties of carbides

Carbide	Melting temperature T_m/K	Hardness H_v
TiC	3338	3200
NbC	3773	2400
WC	3073	2000



Microstructure of a K grade (WC-Co) cemented carbide.

Stellite

- It is a non-ferrous alloy consisting mainly of **cobalt, tungsten and chromium.**
- Other elements added in varying proportions are tantalum, molybdenum and Boron.
- It has good shock and wear resistance and retains its hardness at red heat up to about 920^{0}C.
- On account of this property, it is advantageously used for machining materials like hard bronzes, and cast and malleable iron, etc.
- Tools made of stellite are capable of operating at speeds up to 2 times more than those of common high speed steel tools.
- Stellite does not respond to the usual heat treatment process.
- Also, it can be easily machined by conventional methods.
- Only girding can be used for machining it effectively.
- A stellite may contain 40-50%Co, 15-35%Cr, 12-25%W and 1-4% carbon.

Cemented Oxides or Ceramics

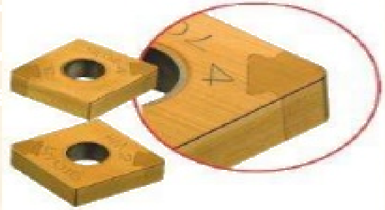
- The introduction of ceramic material as a useful cutting tool material is rather, a latest development in the field of tool metallurgy.
- It mainly consists of aluminum oxide (Al_2O_3), which is comparatively much cheaper than any of the chief constituents of cemented carbides.
- Boron nitrides in powdered form are added and mixed will aluminum oxide powder and sintered together at a temperature of about 1700^{0}C.
- They are then compacted into different tip shapes.
- Tool made of ceramic material are capable of withstanding high temperature, without losing their hardness, up to 1200^{0}C.
- They are much more wear resistant as compared to the cemented carbide tools.
- But at the same time, they are more brittle and possess low resistance to bending.

- With the result, they cannot be safely employed for rough machining work and in operations where the cut is intermittent.
- However, their application for finishing operations yields very satisfactory results.
- It is reckoned that, under similar conditions, the ceramic tool are capable of removing (MRR) 4 times material than the tungsten carbide tools with a consumption of 20 percent less power than the latter.
- They can safely operate at 2-3 times the cutting speeds of tungsten carbide tools.
- Ceramic tool material is used in the form of tips which are either brazed to the tool shank or held mechanically on them as the cemented carbide tips specially designed tool holders are also used for holding these tips.
- Usually no coolant is needed while machining with ceramic tools.

Diamond

- Diamond is the hardest material known and used as cutting tool material.
- It is brittle and offers a low resistance to shock, but is highly wear resistant.
- On account of the above factors diamonds are employed for only light cuts on material like Bakelite, carbon, plastics, aluminum and brass, etc.
- Because of their low coefficient of friction they produce a high grade of surface finish.
- However, on account of their excessively high cost and the demerits narrated above, they find only a confined use in tool industry.
- They are used in the form of bits inserted of held in a suitably designed wheel or bar.
- Diamond particles are used in diamond wheels and laps.

CBN -A new generation cutting tool material



- Polycrystalline cubic boron nitride, CBN, is a material with excellent hot hardness that can be used at very high cutting speeds. It also exhibits good toughness and thermal shock resistance.

- Modern CBN grades are ceramic composites with a CBN content of 40-65%. The ceramic binder adds wear resistance to the CBN, which is otherwise prone to chemical wear. Another group of grades are the high content CBN grades, with 85% to almost 100% CBN. These grades may have a metallic binder to improve their toughness.

- CBN is brazed onto a cemented carbide carrier to form an insert.

- CBN grades are largely used for finish turning of hardened steels, with a hardness over 45 HRc. Above 55 HRc, CBN is the only cutting tool which can replace traditionally used grinding methods. Softer steels, below 45 HRc, contain a higher amount of ferrite, which has a negative effect on the wear resistance of CBN.

- CBN can also be used for high speed roughing of grey cast irons in both turning and milling operations.

- A cermet is a cemented carbide with titanium based hard particles. The name cermet combines the words ceramic and metal. Originally, cermets were composites of TiC and nickel.
- Modern cermets are nickel-free and have a designed structure of titanium carbonitride Ti(C,N) core particles, a second hard phase of (Ti,Nb,W)(C,N) and a W-rich cobalt binder.
- In comparison to cemented carbide, cermet has improved wear resistance and reduced smearing tendencies. On the other hand, it also has lower compressive strength and inferior thermal shock resistance.

Applications

- Cermet grades are used in smearing applications(stains with greasy substance) where built-up edge is a problem. Its self-sharpening wear pattern keeps cutting forces low even after long periods in cut. In finishing operations, this enables a long tool life and close tolerances, and results in shiny surfaces.
- Typical applications are finishing in stainless steels, nodular cast irons, low carbon steels and ferritic steels. Cermets can also be applied for trouble shooting in all ferrous materials.

THANK YOU