Metal cutting: is family of shaping operation, the common factor between them is the removal of material from a starting workpart so the remaining become the desired geometry.

Metal cutting is process consists in removing a material (layer) of metal from blank to obtain the desired required shape & dimensions & with the specified quality of surface finish

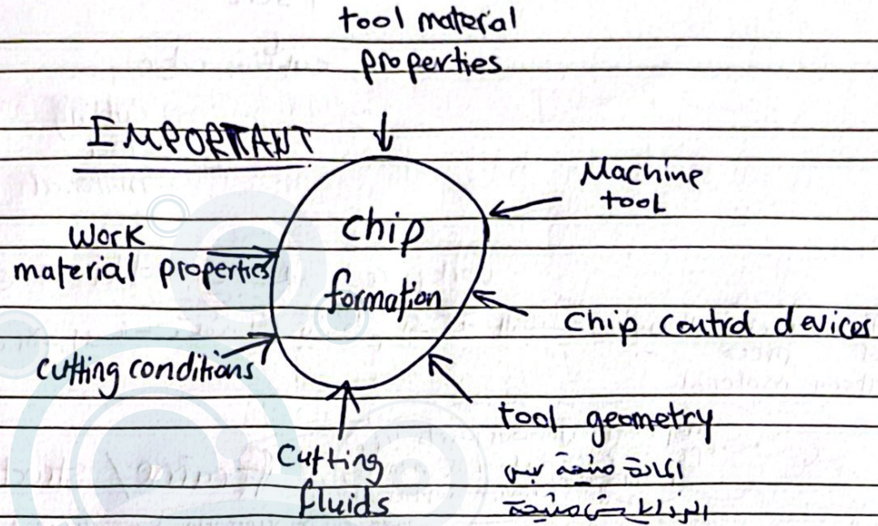
Material removal

- **chipless process** / **Nontraditional processes**
  - various energy forms other than sharp tool cutting, to removal material
  - like → electrochemical
    - → thermal energy process
  - no direct contanct between the cutting tool & workpiece
- **Machining**
  - material removal by sharp cutting tool.
  - like → drilling
    - → turning
    - → milling
    - →
      - Circular
        - Drilling
        - turning
        - Boring
      - other
        - milling
        - shapping
        - planing
        - Broaching
        - gear-generating
- **Abrasive process**
  - Material removal by hard (abrasive) particles
  - like → grinding
    - Bounded
      - grinding
      - Honing
    - loose
      - lapping
      - Polishing
      - Buffing

- Machining
  - → It's performed AFTER other manufacturing process such as forging, cutting, bar drawing
    - these processes creats the general shape of the workpiece (starting workpart)
  - → Machining provides the final shape (desired dimensions & shape) & specifial geometric details that other process can't creat.

Factor Influencing the Chip removal (Formation) process

IMPORTANT



Basic Machine Variables

- cutting speed → the rate at which the workpiece passes by cutting edge (m/s, mm/s)
  ↓
  we can define it
  the speed at which the ~~material~~ (chip) is removed from the surfaces of the workpiece.

  rotational speed → $V = \pi D N$
  - V → cutting speed
  - D → Dia.
  - N → rotational speed (rpm) revolution per minute.

- cutting feed → the rate at which the cutting tool advances into work piece (mm/rev), (mm/min)

- Depth of the cut → the distance the tool is set into the work

Machining technology تكنولوجي

workpiece — cutting tool — Machine tool

cutting tool → cutting edge

Machine tool → الجهاز اللي بينظم (كل ماكينة)

- → Cutting tool material
- → الـ holders اللي بحطوا الـ workpiece
- → الاجزاء المختلفة اللي بتنظم الحركة النسبية مابين الـ work piece material و cutting tool material

1- frame / structure / Bed (support various parts like workpiece, cutting tool & moving parts & provide sufficient strength, rigidity & support to the machine)

الاطار بتاع الـ machine support various part &

وظيفته يتحمل الـ load اللي جاي من القطع و الـ various parts اللي عليه و الـ load اللي جاي من الـ work piece material

ويسوي minimum deflictions

→ عشان الـ cutting action بالـ material removal process

بتعتمد على الـ support و الـ material المصنوعة منها الـ frame / Bed structure (modulus of elasticity) وكيف المادة موزعة حول الـ axis اللي بيعمل deflictions (mass moment of inertia) (second moment of area)

بتعتمد على حركة نسبية مابين الـ cutting tool material و work piece material

فـ اذا صار deflection بالـ تين هدون ↖ او الـ structure (Bed) فالحركة النسبية حتطلع زي ما انا بدي في Quality الشغل

لازم يكون عالي جدا عشان يكون الـ minimume deflition

٢- power unit (motor) electrical / high efficiency / easier control
← بتعطينا الحركة

٣- transimition system ← بينقل الحركة من الـ power unit لـ الاجزاء المتحركة بالـ machine tool
transmit the motion from the power unit to the moving part
← يا الكون من الـ gear box or screw & nuts or pullu pillet

٤- Spindel
← الجزء الدوار بلف بشكل دوراني & make sure that the rotation around the center
← يحمل (turning process) workpiece material
← يحمل cutting tool material (drilling process) (milling)
Like for ex.

Mechanism of metal cutting process

Work table - 0

حسب ال spindel ⇐ اذا كان بتحمل workpice material

ال table ← رح تحمل ال cutting tool

والعكس صحيح

الحركة النسبية بين ال table و spindel حسب الحركة الشكل النهائي للمشغول وال cutting tool

head stock - 1

⇐ to hold & rotate the work piece

permanently fixed at the left end of the lathe, inside it the drive mechanism for rotating the workpiece is suituated

the drive mechanism is a gear box which gives the required speed & Direction of rotation to the work

It also support a hollow shaft called spindle

→ gear box drives the spindle which rotates on it's axis

lead screw - 9

transmits power from the head stock to the carriage for screw thread cutting operation

carriage - 1

It moves the tool allows the guide base parallel to the axis of rotation

It's contain parts that holds the tool & control the motion of the tool

→ saddle

→ cross slide → provide the motion in the direction perpendicular to the axis of rotation ↗ this motion gives the depth of cut in turning

tail stock - 1

It's support the right end of the work piece & also useful supporting the tool like a drill bit during the drilling operation on the lathe

Machine tool: the device that contain the workpiece holders. cutting tool & other parts that control the relative motion between the work piece material & the cutting tool material

1- Bed / structure / Frame

- It's the frame of the machine, it support various parts like workpiece, cutting tool & moving parts & provide sufficient ~~strategy~~ strength, rigidity & support to the machine

- minimum defliction
  ~~becau~~ ↳ depend on the support & the matorial that made of the Bed / Frame (Moment of enertia)
  & كيف اماله موزنة حولين
  deflictions ال axis رز حول ال
  (mass moment of enertia & second moment of enertia)
  minimum ⇐ deflictions ال ↑ ، شان يكون ال ↑ لازم يكون ال

2- power unit → electrical moter, sufficient, high efficiency

3- transimition system → transmit the motion from the power unit to the moving parts

4- spindle → It's the moving part & make sure that the rotation around the center.
  ↳ either contain the material workpiece → turning proc.
  ↳ or cutting tool material → milling & drilling process.

5- Work table

If the spindle hold the material workpiece then the holdr's table will hold the cutting tool material & vice versa.

& the relative motion between the table & spindle will cause the final shape of machining & cutting tool.

6- headstock → fixed at the left end of the lathe, holds and rotate the Workpiece, support a hollow shaft called spindle

7- tailstock → supporting the tool, like drill Bitt during the drilling operation on the lathe.

8- Carriage → contain parts that hold the tool & control the motion of it like (saddle, cross slides) → provide the motion that is in the perpendicular to the axis of rotation this motion gives the depth of cut in

9- lead screw → transmit power from the headstock

(too complex shape)

we can't work with nano machining in traditional machining process
→ planes, circumference

limit لانو ما بيضل dimension for the cutting tool

complexity → moderate → too complex shapes

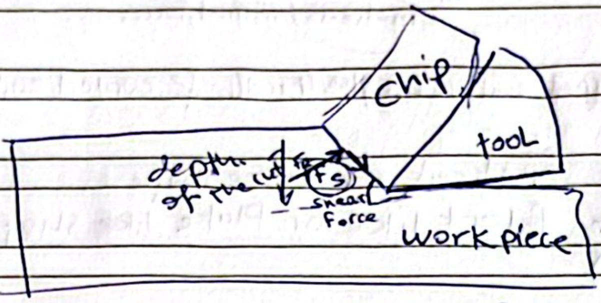
* We do not reach the desired final shape by one pass
  We remove layer by layer in Machining to reach the desired shape, dimension, finish.
  → كل ما زادت ال thickness كل ما زادت المقاومة

Chip removal processes → We have cutting tool (knife)
it do plastic def. in the workpiece material, then do crack
ويتحكم كيف بتحرك ال crack

Chipless process → like water jet machining
↑ كل ما كانت السرعة أعلى
momentum ↑
impulse force ← الشي بالطاقة ح يتحول لـ

Machining →
- Final dimensional accuracy
- Final surface finish
- special features that we can not do in other processes

Mechanism.

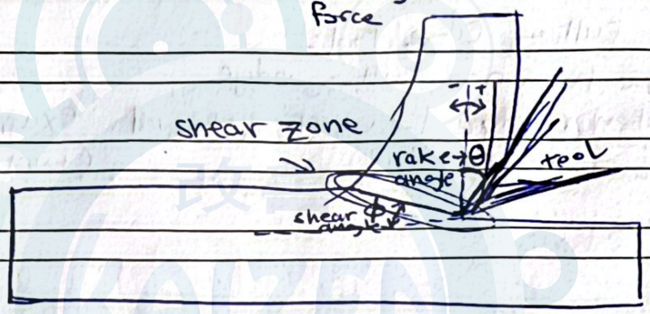


relative motion → friction → temp ↑

If we want to do pentration, I want force تقطع / تنحت

وعشان ال chip رح تتحرك على سطح ال tool

frictional force حتسبب



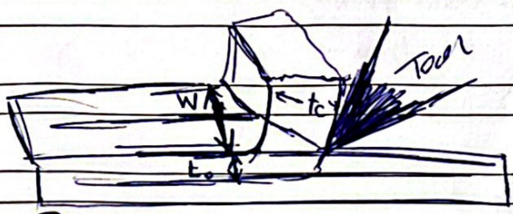
1- the cutting tool exerts a compressive forces on the workpiece

2- that ↑ cause the material of workpiece plasticaly deformed

3- means the material of the workpiece is stresses beyond the yield point causing the material to deform plastically & shear off

3- the plastic flow takes place in a localized region called the shear zone / plane

4- this sheared material begin to flow along the cutting tool face in the form of small piece called chip.



① كل ما زادت ال width حيزيد المقاومة للإزالة

② كل ما زادت ال t_c حيزيد المقاومة

لانو ال shear plane زاد ف ال atoms الي حيصير الها plastic deformation حيكونوا اكتر

Acording to KINEMATICS of the operation
↳ (motions) without forces

- Flat surfaces
- internal & External surfaces cylindrical & curved surfaces

Rotational → cylindrical or disklike shape
non rotational → Block like or Plate like shape
(prismatic)

Cutting tool classification

1. single point tool
   - ↳ one ~~dimens~~ dominant cutting (edge) → not point
   - ↳ point is usually rounded to form a nose radius

   example (Turning)

2. Multiple cutting edge tools
   - ↳ more than one cutting edge
   - ↳ Motion relative to work achieved by rotating.

   example (twist drill), (milling)

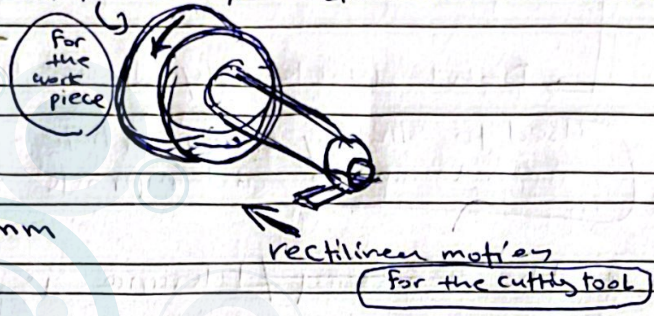
Machining operation

1- turning

the work piece material is connected in the spindle.

circumfrence ما بتتجاوز ١٪ [illegible]

degree of freedom = rotational motion & rectilinear motion



reduction for the diameter.

1 cm → 1 mm penetration = 8 mm
from poth sides

2- Drilling process

the cutting tool move in rotational & rectilinear
2 degree of Freedom for the cutting tool

3- End milling

cutting tool
↓ rotational
↓ 2D rectilinear
3 Degree of fredom system

4- slab milling

cutting tool (cutter)
↓ rotational → 1 Degree of f
work piece → rectilinear
1 Degree of freedome

the final Shape of the machined part depend on the relative motion between the cutting tool & work piece material
(degree of Freedom for the system)

Reaming

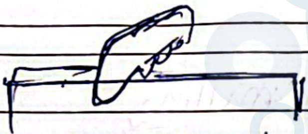
- It's like drilling operation, but we don't remove Bulk material
  we just enhance the dimension accuracy to hole already exist
  OR enhance surface finish for hole already exist.
- Don't work only if we have ~~th~~ certain Diameter

> used to slightly enlarge a hole, provide better tolerance on Diameter, and improve surface finish

* the ~~accuracy~~ / tolerance is ↓↓ than Drilling But accuracy ↑↑ surface finish ↑↑

Milling

- It's 4 axis machines (4 degree of freedome)
- It's multiple cutting edge tool



peripheral milling

axis of the tool is parallel to the surface

face milling

axis of the tool is perpendicular to the surface

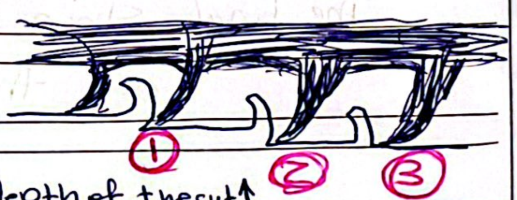
slab milling (plain milling)
to produce a plain, flat horizontal surfaces

Broaching

It's look like sawing

In one pass

- pull
- push



1. depth of the cut ↑ — الهدف نتخلص من مادة ومو هامني ال surface finish & accuracy
2. semi-finishing
3. Finishing — very small pentration — reduce the dimensional accuracy — depth of pentration ↓

This process is performed using multiple tool cutting, the tool is moved linearly relative to the work

Turning → It's single tool removes material from a rotating workpiece to form a cylindrical shape.

* Frame/ Bed / structure → (second moment of area / mass moment of enertia)
  حولين الـ axis الي بتتعرض لل Forces
  لازم يكونوا الارتفاع اكبر من الـ thickness

* gear Box → عدد اكبر الـ power unit الاجزاء المتحركة

(process parameter)
the new surface depend on
↳ Dimensional accuracy for the product
↳ surface quality for the new surface
  - surface integrity
    ↳ micro structure for the new surface
  - surface finish

Internal turning operation → **Boring** → لازم يكون عنا Hole قبل ما نبلش

(Virtical Boring machine)
↓
heavy workpieces provide defliction for the spindle بال turning machine العادية
فبنستخدمها بال machine
الـ spindle منيحة كثير لأنو القطع كانت ثقيلة ما صار relative motion كثير for the workpiece material & cutting tool

Drilling → used to creat a round hole, by means of rotating ~~hole~~ tool with two cutting edges

Turret: to change the active drills

Shapping tool → tool has a linear speed motion, work has occasional Feed motion

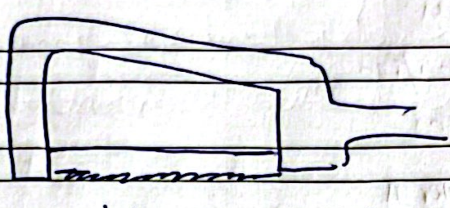
تحرك بعمق ال depth of cut

planing → work has a linear speed motion, tool has occasional feed motion

single	multiple
shaping & planing	sawing
	Broaching

Tapping : used to provide internal screw threads on an existing hole

sawing operations :



Hack saw (the most important saw)

for large cut !

Band saw → ~~for internal cuts~~

flexibility in cutting → linear
→ non linear

Disk saw → circular plates

Carbon tool steel

اعادة الـ بهاشوي

الـ plastic deformation اقل

الـ يستخدم فيها forces اقل للقطع

↓ needed power الـ

tools made up of plain carbon steel can be used for machining soft materials such as brass

Carbides

Metals + carbides

cobalt

carbides → tungsten, tantalum, titanium

tungsten → 90-93 HRC

→ mixed together as powder

↓

compressed to the desired shape

& subjected to heat (temp.)

known as **sinterin**

They can be used at 200-500% greater than the HSS.

They have virtically replaced HSS in high speed & high productin machin

turning & milling process

HSS

- tungsten 18%
- Chromium 4%
- Vanadium 1%

widley used for drilling

← replaced the carbon steel steel.

It can resist a high accumidation in heat

600° يوصل لـ

higher mechanicals properties than carbon tool steel cutting tool material

* It should be stronger (strength) & harder (hardness), from the workpiece — مقاومتها للـ ↑ plastic def.
to withstand forces → compression forces / shear stress

لأنه دايماً الـ cutting يبدأ أولاً بـ plastic def. بعدين shearing
فلو كان مقاومة الـ work piece أعلى من الـ cutting tool الـ plastic deformation
to do plastic def. & shear off — ripping — workpiece material من الـ — يصير الـ plastic deformation بالـ cutting tool material

* can resist the sudden cooling — thermal shock — الّي بتعمله heat generation, friction, relative motion — للي فيها
في درجات الحرارة هاي رح تكون مشكلة → lose the chemical properties & mechanical / melting in the workpiece material

* for example we used to work with steels, but there is a problem that steels can't resist the high temperature, so hardness ↓ we use high-speed steel (Alloys) HSS

very IMP, when used for intermittent cutting → shock loads
* It should be tough enough → the phases in the cutting process is dynamic.

* It should be able to resist high temp → red hardness

* the coefficient of friction between the cutting tool & workpiece material should be as low as possible — total heat ↓ مشان تقلل

* Should easily formed to the required cutting shape.

Ceramics

Aluminum oxide boron nitride powders

mixed together & sintered

at 1700°C

- very hard with good compressive ~~free~~ strength
- ceramics usually in form of disposal tips

Functions of cutting fluids

1. It cools the cutting tool & workpiece
   This make more accurate production & measurment
   Because ~~the~~ that will reduce the temprature, thermal expansion ↓ for both cutting tool & work piece
   accuracy ↑
   - decrease the power consumption

2. It lubricates the cutting tool & reduce the coefficient of friction between chip & tool → increase tool life.

3- reduce wear

4- It causes the chips be break up
   reduce the contact length لي بصير فيه heat generation between tool & chip

5- washes away the chips from tool

6- prevent corrosion of workpiece & machine

7- reduce thermal distortion of the workpiece.

Frictional power = friction force × relative chip velocity

↓

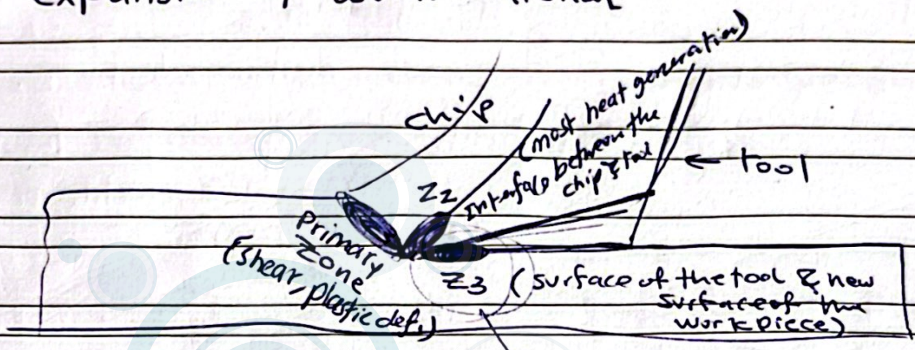
$F = \mu N$

- μ ← morphology of the tool surface
  → refer to detailed structure & features include surface roughness, texture & any wear
- N → depth of the cut (thickness)
- N → properties of material

It can also influence the quality of the finished product.

High cutting temperatures

- Reduce tool Life
- produce hot chips that pose safety hazards to the machine operator
- can cause inaccuracies in part dimensions due to thermal expansion of work material



كل ما تزيد ال thickness
حتزيد القوة الي بتدز ا ل chip
على tool
فحتزيد ال friction

ال tool
عمل penetration (plastic def.)
يعني عملنا جرح لسطح جرحو
elastically (elastic strain)
فحتضغط على ~~flank wear~~ ،
السطح (بس السطح عنو area of contact
صغيرة)
ف ال friction بتكون صغيرة

the relation between the thickness (Depth of the cut) & heat generation is that once Depth of the cut ↑↑, heat generation will increase also Because the normal forces will have a higher value

Properties of cutting fluids

- It should have high specific heat, high heat conductivity

  يلزمه بدو طاقة عالية جداً مشان ترفع درجة حرارته درجة وحدة
  لانو ال heat بينتقل لو كان في فرق واحد بدرجات الحرارة

- It should process good lubricating properties to reduce frictional forces & to decrease the power consumption
- It should be odorless, non-toxic, non-corrosive

Cutting fluids
- Oil Based
  - Straight oils
  - emulsions
- chemical
  - synthetic
  - Semi-synthetic

Additives: Chlorine, sulfur, Phosphorous, biocides, odorants

Factor influencing the ~~cutting~~ Machining operation

1. cutting speed, depth of the cut, Feed, cutting fluids (machine properties) → affect on the forces, power, temp. rise, type of chip, surface finish & integrity

2. tool angle (tool) → As above, flow direction of chip, resistance to wear.

type of chips

3- continous chip → indication of good surface finish, because if so there is a ductile material, appropriate cutting parameters, steady cutting forces

4- Built-up edge chip → indication of poor surface finish & integrity

5- discontinous chip → desirable for ease of chip disposal (no need to use chip Breaker) fluctuating in cutting forces & this will affect the surface finish

6- temprature rise → affect the tool life, crater wear & dimensional accuracy of workpiece may cause thermal damage to workpiece

7- tool wear → Influence the surface finish & intigrity

8- Machinability → Related to the tool life, surface Finish, forces & power & type of the chip.

Major types of material removal processes

1- cutting
2- Abrasive process
3- non traditional (Advanced machining process)

Machining ~~proc~~ operations is a system consisting of ...?

1- workpiece
2- cutting tool
3- Machine tool
4- production personnel

in turning process → the cutting tool (ideal model)
↓
the deformation in the material
be in a well defined shear plane

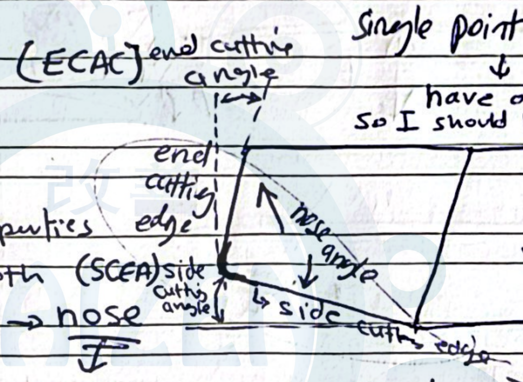
in real cases (sometimes) we don't have well define sheer plane
we will have primary shear zone

Major independent variables in the cutting process

1- Tool material & coating
2- Tool shape, surface finish, and sharpness
3- workpiece material & condition
4- cutting speed, feed, depth of cut
5- cutting fluids
6- characteristic of machine tool
7- work holding & fixturing

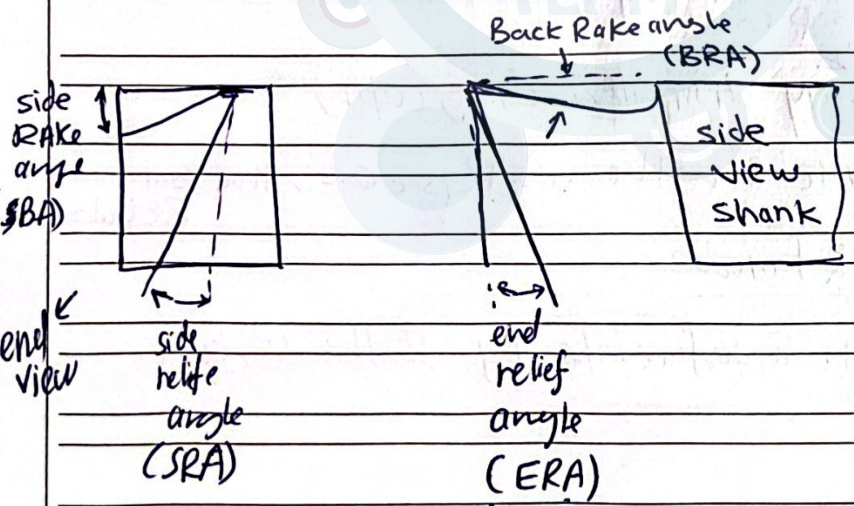
← these factors can be controlled OR adjust by the operator

Single point cutting tool
↓
have one edge cutting so I should have two planes.



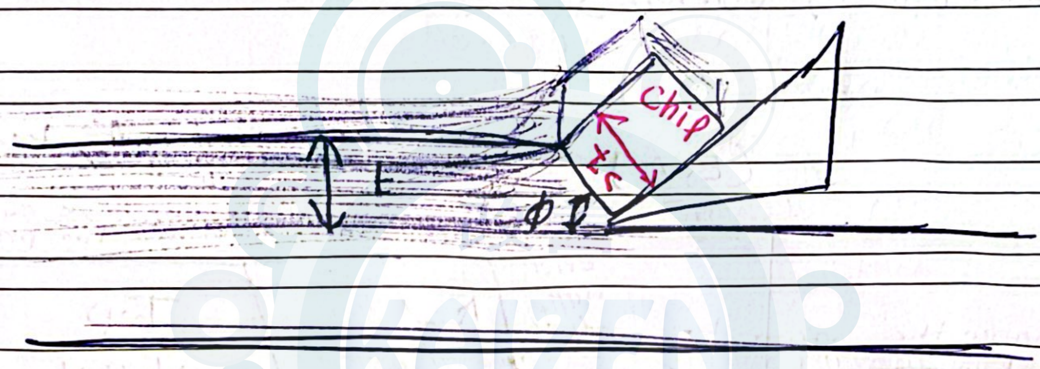
To enhance the properties we did smooth transition → curve → nose
↓
the curved region between two cutting edges → yes we do have two edges but there is just one active cutting edge

- If perpendicular to workpiece → end cutting edge
- parallel → side cutting edge



لتسهيل عملية ال penetration
وما يكون عنا احتكاك
new surface كل شي
flat surface
ال cutting tool

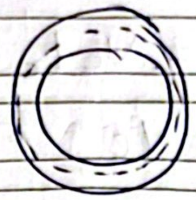
depth of the cut	thickness of the chip
the perpendicular distance (amount) of material being cut into the workpiece	the final thickness of the chip after it is removed & deformed
Affected by Machine settings & tool position	plastic deformation, cutting speed, feed & tool geometry

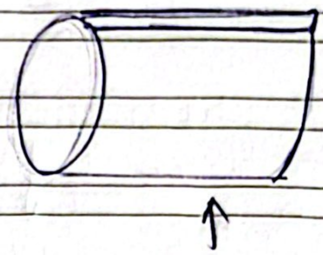


$t_c > t$

Dependent variables in cutting

1- Type of chip produced
2- force and energy dissipated during cutting
3- Temprature rise in the workpiece, the tool & chip
4- Tool wear & failure
5- Surface Finish & surface interity of the workpiece

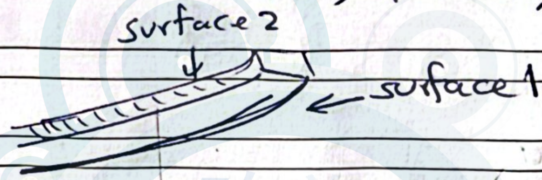


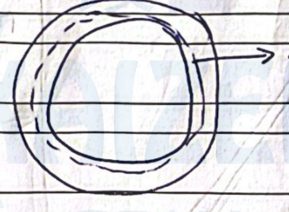


لما احنا عملنا turning process
ومشلنا material 3 ← circumfrence
بس لو بعدين احنا قسمنا طول الchip
اوال removed material حتكون اقل سمك

هون كان عنا
outer surface
ولسه موجود برا

وبعد عملية الcutting صار عنا





so we have 2 new surfaces so the energy in these surfaces ↑↑ very high (unplanced) sys.

that's will cause a shrinkage for the chip length

width more them thickness
لاحظوا الفرق بالعرض والسماكة

so the chip thickness ↑ depth of the cut

in summary → the plastic deformation & shear strain that occur as the material flows during the cutting process will cause t↑, depth of cut

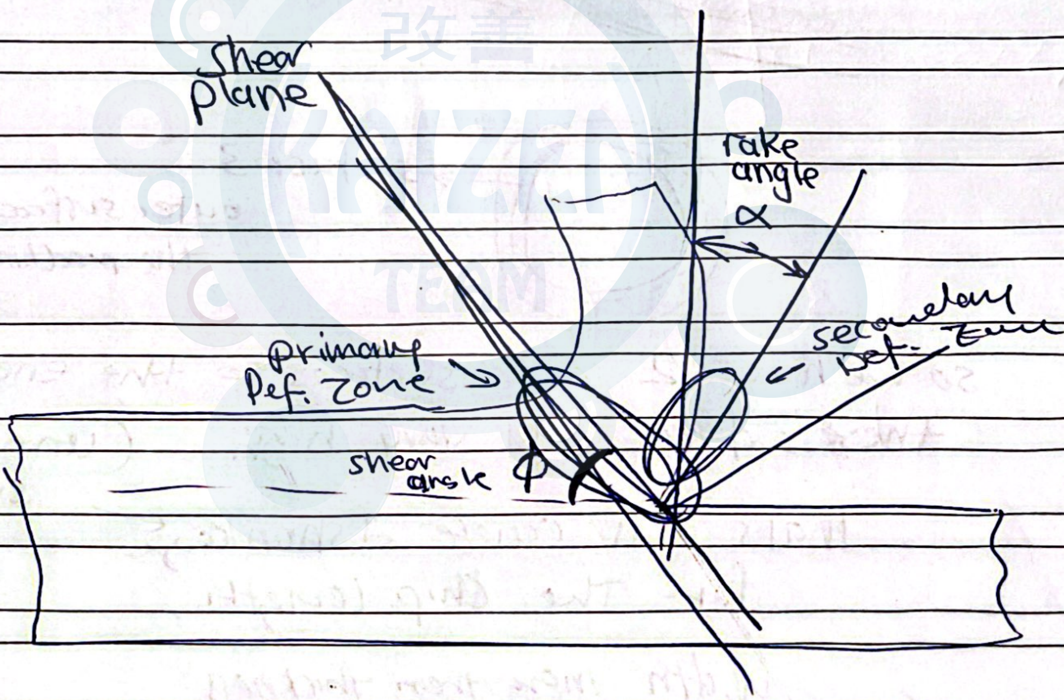
material compressed as it flows over the cutting edge.

$$V t_o = V_c t_c$$

$$V r = V_c = \frac{V \sin\phi}{\cos(\phi - \alpha)}$$

$$\frac{V}{\cos(\phi - \alpha)} = \frac{V_s}{\cos\alpha} = \frac{V_c}{\sin\phi}$$

$$r = \frac{t_o}{t_c} = \frac{V_c}{V}$$

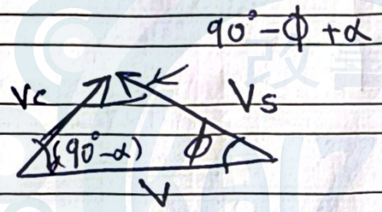


orthogenal cutting → Merchant Model

↓ no cutting ~~edge~~ edge angle (مش مايل)

It's two dimensional & the forces involved are perpinducular to each other

cutting tool has a Rake angle of α & a relief or clearance angle



in sin Rule we can say

$$\frac{V}{\sin(90° - \phi + \alpha)} = \frac{V_c}{\sin\phi} = \frac{V_s}{\sin(90° - \alpha)}$$

V: cutting velocity
Vc: chip velocity
Vs: shear

$$\downarrow r = \frac{t_o \downarrow}{t_c \uparrow} = \frac{\sin\phi}{\cos(\phi - \alpha)}$$

Volume i = Volume f

$r < 1$

$$\text{Shear strain} = \cot\phi + \tan(\phi - \alpha)$$

minimum shear as possible

$$\phi = 45° + \frac{\alpha}{2} - \frac{\beta}{2}$$

$$\rightarrow \phi = 45° + \alpha - \beta \quad (\mu = 0.5 \sim 2)$$

β = friction angle

$\mu = \tan\beta$

4. Discontinuous chips

- consist of segments that attached firmly or loosly to each other

Form under these conditions:

- Low stiffness of the machine tool
- Brittle material
- very low or very high cutting speeds
- Large Depth of the cut
- material with hard inclusions and impurities
- Low RAKE angle
- lake of an affective cutting fluids

Types of chips

1. continous chips

- formed with ductile materials machined at high cutting speeds and/or high rake angles
- Deformation takes place along narrow shear zone (primary shear zone)
- continous chips may develop a secondary shear zone due to high friction at the tool-chip interface

2. Build-up Edge (BUE) chips

- consist of layers of material from the workpiece that are deposite on the tool tip
- As it grows larger, the BUE Become unstable & Break up

BUE can be reduced:

- increase the cutting speeds
- Decrease the Depthe of the cut.
  - normal forces لـ كل ما زادت كل ما كانت محتاج انو يحصل penetration اكبر للسطح
- USE a cutting tool that has lower chemical affinity for the workpiece material
- Increase the RAKE ANGLE
  - يقلل الـ normal forces
- USE sharpe Tools
- USE effective cutting fluids

3. Serrated chips / segmented / nonhomogenous

They are semi-continuous chips with large zones of low shear strain & small zones of high shear strain

→ chips have sawtooth-like approach

Types of chips producel

1- Chip curl

↳ chips will develop a curvature (chipcurl) as they leave the work piece surface

Factors that affect the chip curl conditions

- Distribution of stresses in the primary & secondary shear zones
- cutting fluids
- Thermal effect
- geometry of the cutting tool
- Work-hardening characterstics of the workpiece material

we can change the rake angle (by putting the chip breaker) either we put a clamp or by changing the tool geometry to control chip flow

Chip length obtained = 96 mm
Uncut chip length = 240 mm
Rake angle = 20°
Depth of the cut = 0.6 mm
Horizontal & virtical component of cutting force = 2400 N & 240
F_c F_t

1- shear plane angle
2- chip thickness
3- Friction angle
4- Resultant cutting force

1- $\phi = \tan^{-1}\left(\frac{r\cos\alpha}{1 - r\sin\alpha}\right) = \tan^{-1}\left(\frac{0.4\cos 20}{1 - 0.4\sin 20}\right) = 23.5^\circ$

to find $r \longrightarrow L_2 \cdot W \cdot t_2 = L_1 W t_1$

$r = \frac{t_1}{t_2} = \frac{L_2}{L_1} \Rightarrow \frac{96}{240} = 0.4$

2- $0.4 = \frac{t_o}{t_c} = \frac{0.6}{t_c} = 1.5\ mm$

3- $\lambda = \tan^{-1}\mu = \tan^{-1}(0.48) = 25.64^\circ$

$\mu = \frac{F_t\cos\alpha + F_c\sin\alpha}{F_c\cos\alpha - F_t\sin\alpha} = \frac{240\cos 20 + 2400\sin 20}{2400\cos 20 - 240\sin 20}$

$= 0.48$

$R = \sqrt{F_c^2 + F_t^2} = \sqrt{2400^2 + 240^2} = 2412N$

rake angle = 10°

$\mu = 0.85$

$t = 2.5\,mm$

(Feed) $d = 1.5\,mm$ $V_c = 40\,m/min$

$W = 15\,mm$

(shear strength) $\tau = 650\,N/mm^2$

1- $r = \frac{t}{t_c} = \frac{1.5}{2.5} = 0.6$ $\frac{\text{depth of cut}}{\text{Thickness}}$

2- shear angle:

$\phi = \tan^{-1}\left(\frac{r\cos\alpha}{1-r\sin\alpha}\right) = \tan^{-1}\left(\frac{0.6\cos 10°}{1-0.6\sin 10°}\right) = 33.4°$

3- Shear force

$F_s = \tau \cdot A$

$A\sin\phi = A'$

$A\sin\phi$ = width × depth of cut

$A = \frac{15 \times 1.5}{\sin(33.4)} =$

$F = 650 \times 40.873$

$= 26.57\,N$

4- Friction angle

$\lambda = \tan^{-1}\mu = \tan^{-1}(0.85) = 40.36°$

5- Cutting force

$F_c = R\cos(\lambda-\alpha)$

$60.088\cos(40.36-10)$

$= 51.85\,KN$

$R = \frac{F_s}{\cos(\phi+\lambda-\alpha)}$

$= \frac{26.57}{\cos(33.4+40.36-10)}$

$R = 60.088\,KN$

(Thrust Force) $F_t = R\sin(\lambda-\alpha)$

$60.088\sin(40.36-10)$

$= 30.37\,KN$

6- power consumed $= F_c V_c = 51.85 \times 10^{-3} \frac{40}{60} = 34.57\,KN$

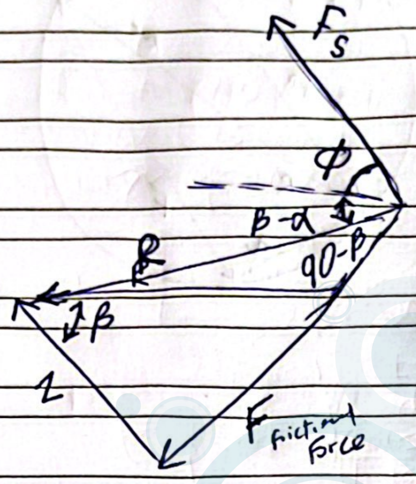
(given)

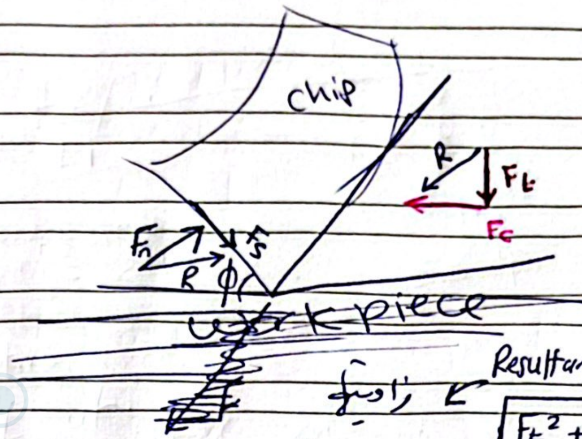
Orthogonal → the direction of the tool velocity & the tool cutting edge perpendicular
→ shear force acts on a smaller area

Oblique → the cutting edge of the tool is at angle less than 90° to the direction of tool travel
→ shear force act on larger area
↓
tool have longer life

Shaving & skiving

$F = F_t + F_c \tan\alpha \cdot \frac{\sin}{\cos}$





Resultant = $\sqrt{F_t^2 + F_c^2}$

$\beta - \alpha$ → frictional angle

rake angle

Shear force: $F_s = F_c \cos\phi - F_T \sin\phi$

Normal force: $F_N = F_c \sin\phi + F_T \cos\phi$

Frictional force: $F = F_c \sin\alpha + F_T \cos\alpha$

$N = F_c \cos\alpha - F_T \sin\alpha$

$\beta = \tan^{-1}(\mu)$

Shear strain: $\varepsilon_s = \cot(\phi) + \tan(\phi - \alpha)$

$P_c = F_z \times V$

Shear stress: $\tau_s = \frac{F_s}{w.t} \sin\phi$

Normal stress: $\sigma_n = \frac{F_n}{w.t} \sin\phi$

$F_s = R\cos(\phi + \beta - \alpha)$

$F_n = R\sin(\phi + \beta - \alpha)$

* $F_c = R\cos(\beta - \alpha)$

$F_T = R\sin(\beta - \alpha)$

$F = R\sin\beta$

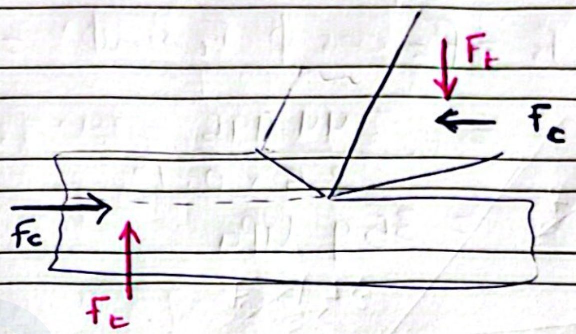
$N = R\cos\beta$

$R = \sqrt{F^2 + N^2}$ (F: friction force, N: normal force)

$$\tan\beta = \mu = \frac{F}{N} = \frac{F_t + F_c\tan\alpha}{F_c - F_t\tan\alpha}$$

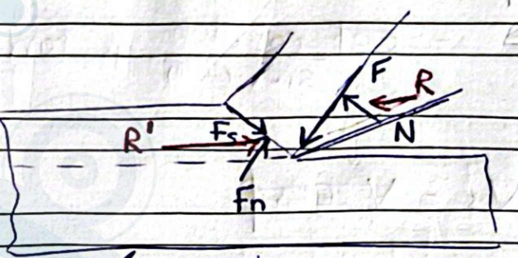
F_t: axial feed force
(Thrust force)

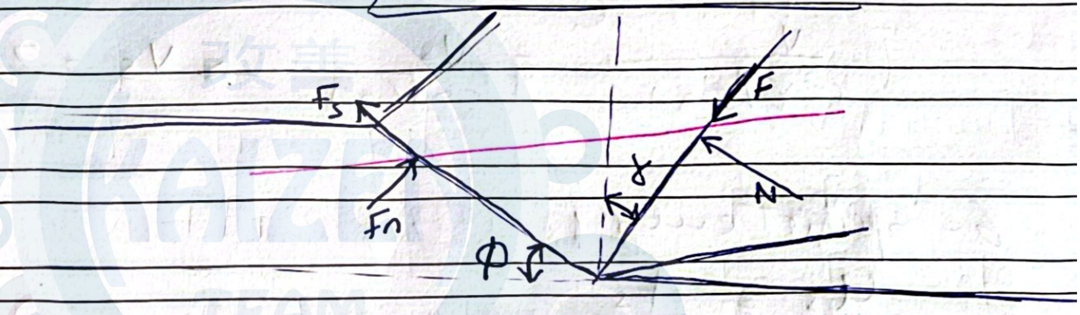
F_c: Tangential force
(cutting=)

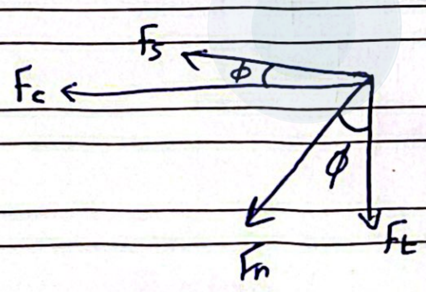


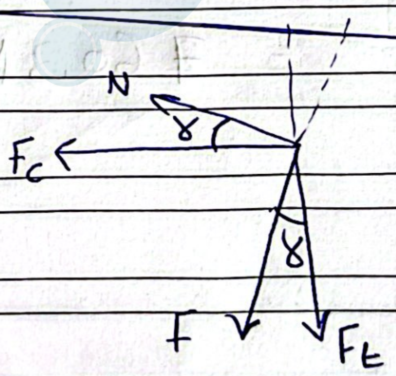
Fs (shear force)

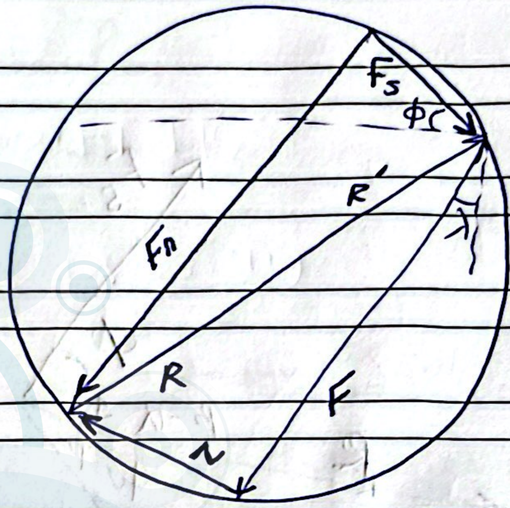
Fn (normal force)










Fs
ϕ
R'
Fn
R
F
N
λ

3- $\tau = \frac{F_s}{w.t} \sin\phi$

$f_s = F_c \cos\phi - F_t \sin\phi = 244.995 \text{ N}$

$= \frac{244.995 \approx 240}{2.5 \times 0.13} \times \sin(28.41)$

$= 359 \text{ MPa}$

4- $\gamma = \cot(\phi) + \tan(\phi - \alpha)$

$= \frac{\cos(28.41)}{\sin(28.41)} + \tan(28.41 + 5) = 2.51$

5- $V_s = \sim\sim$

$\frac{V}{\cos(\phi - \alpha)} = \frac{V_s}{\cos(\alpha)} \rightarrow V_s = 2.38$

6- specific energy

$U_s = \frac{F_s}{w t}$

$= 760.3 \text{ N/mm}^2$

$t_o = 0.13$ mm
$w = 2.5$ mm
$\alpha = -5°$
$V = 2$ m/s
$t_c = 0.23$ mm
$F_c = 430$ N
$F_t = 280$ N

$\phi = ?$ Don't use the approximation eq.

$$\phi = \tan^{-1}\left(\frac{r\cos\alpha}{1 - r\sin\alpha}\right) = \tan^{-1}\left(\frac{0.57\cos(-5)}{1 - 0.57\sin(-5)}\right)$$

$$r = \frac{0.13}{0.23} = 0.57 \qquad = 28.41°$$

Determine the friction coef.

$$\mu = \tan(\beta)$$

$$R = \sqrt{280^2 + 430^2} = 513.13\,N$$

given α, ϕ = ~~28.41°~~, $-5°$, 28.41

$$\beta = \tan^{-1}\left(\frac{F}{N}\right)$$

$$F = 430\sin(-5) + 280\cos(-5) = 241.46\ N$$

$$R = \sqrt{F^2 + N^2} = \sqrt{241.46^2 + N^2} = 513.13$$

$$N = 452.77\,N$$

$$\beta = \tan^{-1}\left(\frac{241.46}{452.77}\right) = 28.07°$$

If another way:-

$$F_c = R\cos(\beta - \alpha)$$

$$430 = 513.13\,(\beta - (-5))$$

بس باقي الكتابة بدخل

$$\cos^{-1}\left(\frac{430}{513.13}\right) = \beta - (-$$

$$\beta = 28.07$$

~~α~~

~~β~~ $= \tan^{-1}\left(\frac{F_t}{F_c}\right)$

C_1 (cutting speed = 375 ft/min
Tool Life = 5.5 min
n = 0.137

C_2 (expected tool life T_2 = ?
cutting speed = 300

$$C = VT^n$$

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

$$375\,(5.5)^{0.137} = 300\,(T_2)^{0.137}$$

$$T_2 = 28.04 \text{ min}$$

$$375 \times 5.5^{0.137} = C$$

$$4737 = C$$

$$\frac{300\,T^{0.137}}{300} = \frac{4737}{300}$$

$$0.137 \times \ln T = \ln\left(\frac{4737}{300}\right)$$

$$\ln T = \frac{0.4567}{0.137}$$

$$e^{\frac{0.4567}{0.137}} = 28.04 \text{ min.}$$

cutting force = 1470 N

Thrust force = 1589 N

α rake angle = 5°

w = 5 mm^2

thickness before cut = 0.6

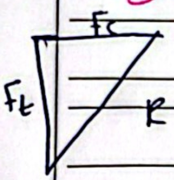
Thickness ratio = 0.38

$r = \frac{t}{t_c}$

$0.38 = \frac{0.6}{t_c}$

$t_c = 1.58$

a) shear strength



$\tau = \frac{F_s}{w \cdot t} \sin\phi$

$F_s = F_c \cos\phi - F_t \sin\phi$

$1470 \cos(21.38) - 1584 \sin(21.38) = 789.52 N$

$\phi = \tan^{-1}\left(\frac{r\cos\alpha}{1 - r\sin\alpha}\right) = 21.38°$

$\tau = \frac{789.52}{5 \times 0.6} \sin(21.38) = 95.9 MPa$

b) Coeff. of friction

$\mu = \tan\beta$

$F_c = R\cos(\beta - \alpha) \Rightarrow 1470 = 2164.7 \cos(\beta - 5)$

$R = \sqrt{1470^2 + 1589^2} = 2164.7 N$

$\cos^{-1}\left(\frac{1470}{2164.7}\right) = \beta$

$= 1.291$

$\beta = 52.23°$

if not orthogonal

$\phi = 45 + \frac{\alpha}{2} - \frac{\beta}{2}$

$\beta = 52.24$

$\mu = \tan\beta = 1.29$ ✓

orthogonal cutting op.

$t_o = 0.13$

$V = 120\ m/min$

$\alpha = 10°$

$W = 6\ mm$

$t_c = 0.23\ mm$

$F_c = 500\ N$

$F_t = 200\ N$

calculate the percentage of the total energy that goes into overcoming friction at the tool chip interface?

$\frac{FV_c}{F_c V} = \frac{F\,r}{F_c}$

material removal rate

$F = F_c \sin\alpha + F_t \cos\alpha$

$= 500 \sin 10 + 200 \cos 10 = 283.78\ N$

$r = \frac{0.13}{0.23} = 0.57$

$= \frac{283.78 \times 0.57}{500}$

$= 32.35\ \%$

Temp. distribution

- The temp. increase with cutting speed
- chip can become red hot & creat a safety hazard
- The chip carries away most of the heat generated

Higher cutting speeds → better heat dissipation via the chip reducing thermal damage to the work piece & tool

Temprature rise

lower the strength, hardness stiffness & wear resistance of cutting tool

cause uneven dimensional changes

Induce thermal damage & metallurgical changes in the machine surface

$$T = \frac{0.000665\, Y_f}{\rho c}\sqrt{\frac{V t_o}{K}}$$

Y_f → flow stress

V → velocity

t_o → depth of the cut

K → thermal conductivity

ρc → heat capacity

$$T_{mean} \propto V^{a} f^{b}$$

= تجريبية

primary zone (shear zone)

secondary zone (tool-chip interface)

- length of contact ↑ ازاد
- friction ↗ بزيد
- even though we have use collant because there is no gap to enter

Zone three ~~between~~ interface between the surface of too & new surface

there is collant effect & high rake angle.

$D = 12.7$ mm

$d = 60$ mm $\theta = 118^\circ$

$V_c = 25$ m/min

feed = t_o = 0.3

$V = 60$ m/min $\times 60$ $\quad V = \pi D N$

$60 = \pi (4) N$

$N = \dfrac{60}{\pi (4 \times 0.0254)}$ in→m

$= 187.9$ rpm

1-22-2
H

$i = 20^\circ$, tool tilted

$\alpha_n = 10^\circ$

$w = 0.2$ inch

$t_o = 0.1$ in

$\tau_s = 50{,}000$ Ib/in^2

$r = 0.4$

$N = 400$ rpm

1) cutting forces

2) $P_{spindle}$

3) $power_{shear} = F_s V_s$

$P = F_c V$

$\alpha_e = \sin^{-1}(\sin^2 i + \cos^2 i \sin \alpha_n)$

$= 15.68^\circ$

$\tau_s = \dfrac{F_s}{w t_o} \sin\phi$

$50{,}000 = \dfrac{F_s}{0.2 \times 0.1} \sin$

$\phi = \tan^{-1}\left(\dfrac{r\cos\alpha}{1 - r\sin\alpha}\right) = \tan^{-1}\left(\dfrac{0.4\cos 15.7}{1 - 0.4\sin 15.7}\right)$

$= 23.35^\circ$

$F_t = R\sin(\beta - \alpha) =$

$F_c = R\cos(\beta - \alpha) =$

$\tau_s = \dfrac{F_s}{w t_o}\sin\phi \rightarrow F_s = 2523$ Ib

$\phi = 45^\circ + \dfrac{\alpha}{2} - \dfrac{\beta}{2}$

$\beta = 58.98^\circ$

$F_s = R\cos(\phi + \beta - \alpha)$

$2523 = R\cos(23.35 + 58.98 - 15.7)$

$R = 6365.64$ Ib

السؤال الي حطه الدكتور عشان تحلو

Depth of cut $= t_1 = 0.13\ mm$

Width $= w = 2.5\ mm$

rake $= \alpha = -5^\circ$

$V = 2\ m/s$

$t_c = 0.23\ mm$

$F_c = 430N$, $F_t = 280N$

1- $\phi = \tan^{-1}\left(\frac{r\cos\alpha}{1 - r\sin\alpha}\right) = \tan^{-1}\left(\frac{0.57\cos(-5)}{1 - 0.57\sin(-5)}\right) = 28.4^\circ$

$r = \frac{t_1}{t_2} = \frac{0.13}{0.23} = 0.565 \approx 0.57$

2- $\mu = \tan(\beta)$

$= \frac{F_t + F_c\tan\alpha}{F_c - F_t\tan\alpha}$

$= \frac{280 + 430\tan(-5)}{430 - 280\tan(-5)}$

$= 0.53$

$R = \sqrt{F_c^2 + F_t^2}$

$= \sqrt{430^2 + 280^2}$

$= 513.13N$

~~$F_c = R\cos(\beta - \alpha)$~~

7- $\mu_f = \frac{F r}{w t_o}$

$792.5 = \frac{0.57 \times F}{2.5 \times 0.13}$

8- $\mu_s = \frac{F_s V_s}{w t_o V} = 904.8$

3- $\tau = \frac{F_s}{w \cdot t}\sin\phi$

$F_s = F_c\cos\phi - F_t\sin\phi$

$= 430\cos(28.4) - 280\sin(28.4) = 245.07N$

$= \frac{245.07}{2.5 \times 0.13}\sin(28.4) = 358.66\ N/mm^2$

4- $\epsilon = \cot(\phi) + \tan(\phi - \alpha) = 2.5$

5- ~~$\frac{V_{chip}}{\sin\phi}$~~ $V_c = ?$ $\quad \frac{V}{\sin(90 - \phi + \alpha)} = \frac{V_c}{\sin\phi}$

6- $\frac{V_s}{\sin(90 - \alpha)} = \frac{V}{\sin(90 - \phi + \alpha)}$ $\quad \frac{2}{\sin(90 - 28.4 + (-5))} = \frac{V_c}{\sin(28.4)}$

$V_s = 2.4\ m/s$ $\quad V_c = 1.14\ m/s$

Allowable wearland

- cutting tools need to be replaced when:
  1- surface finish of the machined workpiece begins to deteriorate
  2- cutting forces increase significantly
  3 - Temp. rises significantly

Example 21.3

cutting speed is 60 m/min, tool life is 40 min

travel distance = 60 x 40 = 2400 m

when cutting speed is increased to 120 m/min

tool life reduced 5 min & travel 600 m

عشان نشوف ال production rate

5 x X = 40

x = 8

then 600 m x 8 = 4800

4800 > 2400

part

- crater wear occurs on the rake face of the tool

Factors affect (influencing) creater wear

1- temprature at the tool-chip interface

2- the chemical affinity between the tool & workpiece material

3- Diffusion rate increases with increasing the temp.

crater wear increase as temp. increase

surface Quality:
- surface finish & dimensional accuracy of machined part, geometric features
- surface integrity & microstructure of the new surface (machined part) & material property.

Stainless steels:

Austenitic	Ferritic	Martensitic
BCC	FCC	deformed Structure
difficult to machine	good Machinability	Abrasive
(300 series)	(300 series)	(400 series)

Thermally assisted Machined

(hot machining) → a source of heat is focused onto an area just ahead of the cutting tool

Advs:-
- → Reduce cutting force
- → increase tool life
- → Higher material-removal rate
- → Reduced tendency for vibration & chatter

Factors influencing the surface integrity

- Temprature generated
- Surface residual stresses
- Plastic def. & strain hardening

Machinability

- surface finish & surface integrity
- Tool Life
- force & power required
- The level of difficulty in chip control

good Machinability indicate good surface finish & surface interity, long tool life, & low forces & power req.

Machinability

Ferrous Metal

- Steels
  - If a carbon steel is too ductile that will cause to produce build up edge ⟶ poor surface finish
  - If too hard, It can cause abrasive wear because of presene of carbides in the steel
- leaded steel
  - high percentage of lead solidified at the tips of manganese sulfide inclusions
- Calcium-deoxidized steels
  - oxide flakes of calcium silicates (CaSiO) that reduce the strength of the secondary shear zone & decrease tool chip interface friction & wear.

effect of various elements in steels
presence of aluminum & silicon as they combine with oxygen ⟶ aluminum oxide and silicate that are abrasive and hard ⟶ ~~reduce~~ tool wear

Non ferrous ~~metal~~

- Aluminum & Magnesium
  - EASY TO MACHINE with good surface finish & prolonged life tool
- Beryllium
  - ↳ machining in a controlled environment
- cobalt-based alloys
  - ↳ requires sharp, abrasion-resistant tool material & low feed & speeds
- copper
  - ↳ difficult to machine because of build up edge form
- Titanium ⟶ very poor thermal conductivity
- Tungsten ⟶ brittle, strong & very abrasive

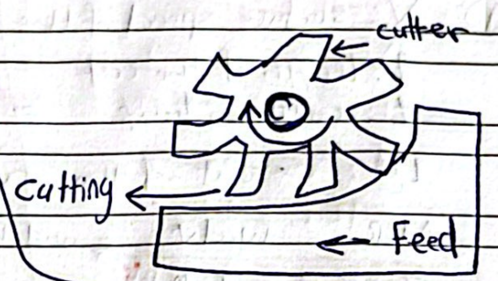
reduce Machinability & increase tool wear

(Chapter 24)

Milling

→ a process in which a rotating multi-tooth cutter removes material while traveling along various axes with respect to the workpiece.

good surface finish / great accuracy

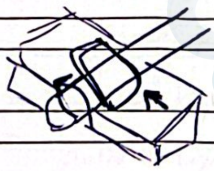


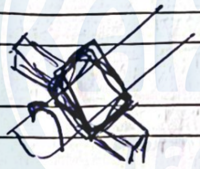
types of milling

- **peripheral Milling (plain milling)**
  ↓
  axies of cutter rotation is parallel to the workpiece surface & accomplished by peripheral teeth

- **Face milling**
  ↓
  axies of cutter rotation is perpendicular to the workpiece surface
  accomplished by flat face

- **End milling**
  end mill cutter to cut variety of shapes





When the width of the cutter is greater than the width of the work piece material (Slab milling)

cutter is longer than the width of the cut.

- Ball-End Milling
  → For machining complex 3D ~~cutter~~ shapes
  → provides smooth finishes due to it's rounded cutting edge

- CNC Milling of sculptured surface

N: rotational speed (rpm)

f: feed per tooth mm/tooth $= \frac{v}{Nn}$ → linear speed of the work piece or feed rate

(Nn → عدد الأسنان)

D: cutter diameter

n: no. of teeth

v: linear speed of the workpiece or the feed rate $\frac{mm}{min}$ (in/min)

(cutting speed) V: surface speed of the cutter $= \pi D N$

l: length of the cut

t: cutting time $= (L + L_c) / v$

L_c: extent of the cutters first contact with workpiece $L_c = \sqrt{Dd}$ (d → depth of the cut)

MRR = w d v → width of the cut

if slab milling length of the cutting edge ~~width of the workpiece~~ then we do $= \frac{w}{n}$ (width of the w/p)

Torque $= F_c \frac{D}{2}$ (N.m) (F_c → cutting force)

power = Torque . ω → 2πN (kW or hp)

Example 24.1 in slides

L = 300 mm , 100 = W

f = 0.25 mm/tooth

d = 3 mm

D = 50 mm

n = 20

N = 100 rpm

$MRR = \frac{Lwd}{t} = wdv = 100 \times 3 \times 500 = 150{,}000\ mm^3/min$

$f = \frac{V}{Nn} \rightarrow 0.25 = \frac{V}{20 \times 100}$

V = 500 mm/min

Torque $= F_c \frac{D}{2}$

(F_c → we don't have any forces)

so from the table (given that we have annealed mild steel)

$U = 3\ W.s/mm^3$ (s → second)

$U = 3 \times \frac{150000}{60} = 7500\ W$

$Torque = \frac{power}{\omega} = \frac{7500\ (60)}{2\pi\ (100)} = 716.197\ N.m$ (60 → min لتحويل)

$t = \frac{(L + L_c)}{v} = \frac{300 + \sqrt{50 \times 3}}{500} = 0.624\ min = 37.4\ sec$

Milling Operations

Conventional milling / UP milling

the direction of the rotation of the cutter & Direction of the workpiece is oppoiste to each other

- Maximum chip thickness is at the end of the cut
- Adv: tooth engagement is not a function of the work piece surface (Cutting starts with less force)
  that mean it's good for dirty, Scale & rust sufaces because ~~the too~~ it won't damage the tool because the cutting start's with low forces (smooth start).
- D.adv: The cutter can cause the machine to shake (chatter) making it harder to get a precise cut.
- the cutting process is smooth because the cutter gradually (bites) into the material
- the workpiece has a tendency to be pulled upward, so we must clamp ~~the cutter~~ it tightly

Climb milling (DOWN Milling)

move in the same direction (CW)

- cutting starts at the surface of the workpiece.
- Downward compression of the cutting forces hold the workpiece in place
- Because of resulting high impact forces when teeth engage the workpiece
  ↓
  this operation must have a rigid setup & Backlash must be eliminated in the table feed machine
- Not suitable for maching workpiece that have surface scale.

Q2 / Activity 2

peripheral Milling

~~L = 600 mm~~

W = 40 mm

D = 60 mm

n = 10

V = 60 (m)/min

f = 0.15 mm/tooth

d = 5 mm

MRR = ?

~~$MRR = w d v = 40 \times 5 \times 60 \times 10^{3} = 12$~~

$MRR = w d V$

$\frac{V}{Nn} = f$ → $\frac{V}{318.31(10)} = 0.15$

$N = \frac{V}{\pi D} = \frac{60 \times 10^{3}}{\pi(60)}$ → to convert it to mm $= 318.31$

Better / $= \frac{60}{\pi(60 \times 10^{-3})} = 318.31$ (to convert it to m)

$V = 477.465$ mm/min

$MRR = 40 \times 5 \times 477.465 = 95493 \text{ mm}^3/\text{min}$

$t = \frac{lwd}{MRR} = \frac{600 \times 40 \times 5}{95493} = 1.257$

→ $\frac{L + L_c}{v} = \frac{600 + \sqrt{60 \times 5}}{477.465} = 1.29$

Face Milling → $L_c = \frac{D}{2}$ (Bad quality)

↳ lead angle on underformed chip Thickness in face Milling

- As the lead angle ↑ underformed chip thickness ↓ length of contact ↑ (chip width)

Range = 0–45

- As the lead angle decreases there is a smaller vertical force comp. (axial force) → the process less demanding on the cutting tool
- The cross-sectional area of the underformed thickness remains constant

High lead angle	Low lead angle
• underformed thickness of the chips ↓	• ↑ underformed chip thickness
(may increase Tool wear) • length of contact ↑	• ↓ length of contact
• Reduces the vertical force component, improving Tool life & surface finish	• high vertical force component increase stress on the tool & workpiece.

entry & exist of the cutter

- entry → the cutter initially engages the workpiece, and the forces build up gradually
- exit → the forces reduce, but ~~undesirable effects~~ improper exit angles can cause undesirable effects such as poor surface finish or tool damage.

End milling

Types:
↳ hemipherical ends (bull-nose mills) for the (3D) production of sculptured surfaces, such on dies & molds
↳ can produce a varity of surfaces at any depth. curved, stepped & pocketed

6- Back striking → Dull cutting too
- → negative tool angle
- → tilting the cutter spindle

7- Chatter marks → insuffecient stiffness of the sys.
- → external Vibration
- → feed, width, depth of the cut too large.

8- Burr formation → Dull cutting edges.
- → ~~incorrect angles of entry or exit~~
- → incorrect insert shapes
- → feed & Depth of the cut too high

9- Breakout → lead angle too low
- → incorrect angle of entry & exit
- → incorrect cutting edge geometry
- → ~~incorr.~~ feed & Depth of cut too high

Burr formation → It's a common defects when the cutting tool doesn't cleanly exits the material

large Breakout → when the cutting tool exits at an unfavorable angle or with excessive force

small Breakout → when ~~the~~ increasing the lead angle of the cutter, BREAKOUT SIZE REDUCED

Q حلوة انتباه

$D = 10.7\,mm$

$L = 50\,mm$

$V = 35\,m/min \longrightarrow N = \frac{V}{\pi D} = \frac{35 \times 10^3}{\pi (10.7)} = 1041.2\,RPM$

$f = 0.4\,mm/rev$

$t = ??$

$t = \frac{L + L_c}{r}$ $\quad f = \frac{r}{Nn} \rightarrow r = 1041.2 \times 0.4$

$= 416.48\,mm/min$

$t = \frac{L}{fN} = \frac{50}{0.4 \times 1041.2} = 0.12\,min$

$= 7.2\,sec.$

Trouble shooting guide for Milling operation

1. Tool Breakage
   - Tool material lacks toughness
   - improper tool angles
   - machining parameters too high

2. excessive tool wear
   - = = = =
   - improper cutting fluids
   - improper tool material
   - improper tool angles

3. Rough surface finish
   - Feed per tooth is high
   - too Few teeth on the cutter
   - tool chipped or worn
   - built up edge
   - vibration & chatter

4. Tolerance too broad
   - lack of spindle & work holding stiffness
   - excessive temp. rise
   - dull tool
   - chips clogging cutter

5. work piece surface burnish
   - Dull tool, depth of cut too low
   - radial relief angle too small

D. ADV. of machining

- wasteful of material
- time consuming process

THE BASIC COMPONENTS OF MILLING MACHINES

- Workstable → in which the work piece is clamped using T-Slots
  The table moves longitudinally relative to the saddle (back & forth)
- Saddle → support the table & can move in the transverse direction. (side to side)
- Knee → support the saddle & gives the table vertical movement so that the depth of the cut can be adjusted & workpieces with various heights can be accommodate.
- overearm → used on horizontal machines, adjusts for different arbor Length (hold longer tools)
- ~~Head →~~ contains the spindle & the cutter holders, & it can be
  ↳ Swivel & adjust For tapered surfaces.
  & adjust it's angle ~~and direction~~ position for cutting

Bed-type Milling Machine → heavy workpieces
Because the bed & ~~table~~ work table are fixed

CNC vertical-spindle milling machine

Axis → relative motion that can be done between workpiece & cutting tool material

- x
- y
- z

x, y, z } recteliner } rotational

اقصى حد للحركة ← 6

=

كل ما تزيد الـ degree of freedome
تزيد أسعار بيعها و
حيكونه تقدر تسوي الأشكال اكثر

Why Machining is IMP.?

- variety of work material can be machined (applied to metals)
- good dimensional accuracy & surface finish
- varity of parts, & special geometry

Drilling

is the operation of producing circular hole in the workpiece by rotating cutter

cost ↓ accuracy مش عالية و الـ surface finish مش عالي ← drilling machine ← بنستخدمها hole لـ

turning machine ←, milling ← — أعلى تشطيب ↑

- The drilling operation can also be accomplished in lathe in which the drill is held in tailstock & the work is held by the chuck
- The most common Drill is the twist drill
- the Drilling machine is the simplest & accurate machine used in production shop in which the work piece is held stationary (clamped in position) & the drill rotates to make a hole.

Types of Drilling Machine

- Based on construction
  - portable
  - sensitive — حساسة بايدي — الـ feed بايدك (1.5 – 15) mm — operator manually sense the cutting action, making it (sensitive)
  - Radial — حسب حركة الـ head
  - up-right — up to 50mm (5cm)
  - gang
  - Multi-spindle → بيعمل أكتر من process في نفس الوقت
- Based on Feed
  - Hand
  - Power Driven

Up-right Drilling Machine
The table moves vertically & radially

Radial Drilling Machine → It's the largest & most versatile type of drilling medium to large & heavy workpieces.

Tool holding devices

for holding the drill spindle

- → by directly fitting in the spindle hole
- → by using drill sleeve
- → by using drill socket
- → by using drill chuck → most commonly used in portable drills.

Types of cutter

1- Reamers

Multi tooth cutter to enhance the surface finish for existing hole

Accuracy of 0.0005 mm can be achieved

2- Boring Tool

Single point cutting Tool

Accuracy of 0.005 mm can be achieved

3- Countersinks

special angled cone shaped enlargement at the end of the hole

cutting edges at the end of conical surfaces

4- Counter Bore Tool

special cutter uses a pilot to guide the cutting action two most common types

- HSS Drill
  - 18-4-1 (tungsten, chromium, → vanadium)
  - ↓ Low cost
- Carbide-tipped drills
  - high production rate & in CNC

Other types

- → Solid carbide drill
- → TIN coated drills

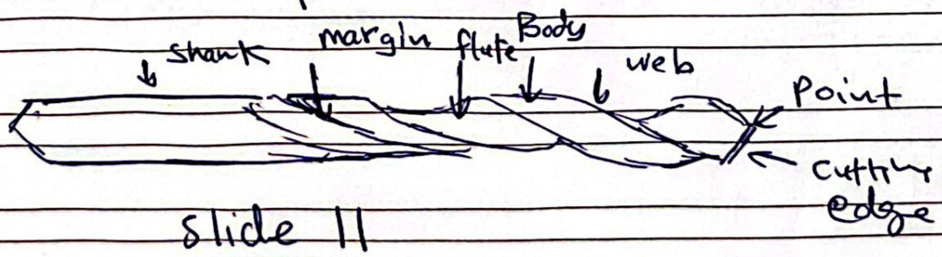
types of Drills

- Twist drill
- step drill: produces holes of two or more different diameter
  - ↳ core drill used to make an existing hole bigger
- straight-flute
- spade
- gun

Drilling operation

- Drilling center hole

Twist Drill → p80



slide 11

* precautions for Drilling machine

1 - Lubrication
2 - Machines should be cleaned after use
3 - Chips should be removed using brush
4 - Machines should be lightly oiled to prevent from rusting

* Safety precautions

see slide 27

Q1) Activity 2

$D = 10.7$ mm
$d = 60$ mm
$\theta = 118°$
$V = 35$ m/min
$f = 0.4$ mm/rev

$V = \pi D N$

$d = \frac{D}{2}$ mm

$MRR = \frac{\pi D^2}{4} \times f \times N$ (mm/rev, rev/min)

$t = \frac{L}{f N}$ (L: length of the hole)

$t = \frac{L}{fN}$

$N = \frac{V}{\pi D} = \frac{35 \times 10^3}{\pi (10.7)} = 1041.2$ rpm

~~$d = \frac{D}{2} = \frac{10.7}{2} = 5.35$~~ → $d = \frac{D}{2} \cdot \tan\left(\frac{\text{Point Angle}}{2}\right)$ (make sure that this ✓)

$d = 8.9$

$L = 60 - 8.9 = 51.5$ mm

$L = 60 - 5.35 = 54.65$

$t = \frac{54.65}{0.4 \times 1041.2} = 0.1312$ min

$MRR = \frac{\pi (10.7)^2}{4} \times 0.4 \times 1041.2$

$= 37449.98$ mm³/min

OR

$D = 10.7$
$L = 60$

$t = \frac{60}{0.4 \times 1041.2} = 0.144$ min

$MRR = \frac{\pi (0.7)^2}{4} \times 0.4 \times 104.12 =$ ~~8.6 sec~~ ~~0.144 min~~ 37,450 mm³/min

27

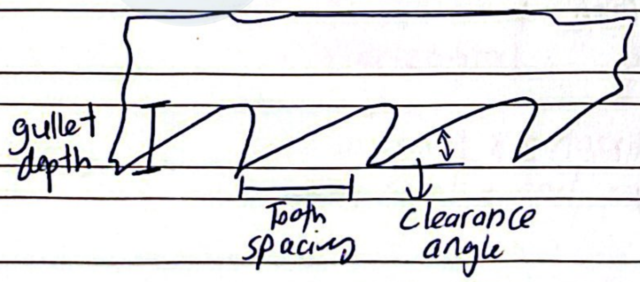
- Abrasive disk sawing
  - uses an abrasive wheel to cut through hard ~~metal~~ materials
  - used for → wet cutting
    → dry cutting → up to 80 m/s
  - Better finish & accuracy than steel friction blades.
- Band saw
  - uses a long, continous band with teeth on one edge.
    Can handle → straight
    → curved cuts.
  - Band friction cutting → operates at high speeds (15 – 75 m/s)
    → used for thin ferrous metals & some thermoplastic material
  - Diamond band cutting → diamond-impregnated band
    → used to cut hard materials like glass, ceramics, carbide, dies & hard semiconductor materials
  - For finishing & polishing use a file band instead of saw band.

LINEAR METAL CUTTING ACTIONS: SAWING, BROACHING & SHAPING

* Sawing.
  - → Hacksaw
    - types
      - → manual
      - → semi-automatic
      - → fully automatic
    - features
      - → positive feed & exact depth of cut for each stroke
      - → uniform pressure feed
      - → gravity feed → uses the weight of the saw for cutting force
      - → lubricant
  - → Circular saw
    - Bladetype
      - Solid → for smooth cutting of smaller or softer material
      - segmented type → for cutting large or tough material

* cutting speed
  - for ferrous metal 0.1 − 0.4 m/s
  - for nonferrous metal 1 − 20.3 m/s → these metals tend to stick to the blade due to friction & heat

cutting ability → dependent on the metal structure, & it's melting characteristics



Advantages for mass production
↓
1- roughing & finishing
in on pass
2- short cutting time
3- versatility → internal surface,
↳ external =
4- high production tolerance
5- good surface finish
6- Burnishing effect

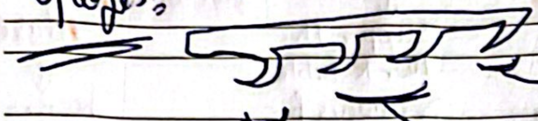
Disadvantages
↓
1- high tool cost
2- not advisable for short run
3- Rigid part support needed.
4- limited to single operation

Broaching

removal of material in one stroke

High rake angle
↓
high quality
↓
lower friction

stages:



- Rough machining
- intermediate depth of cut
  - Better accuracy & surface finish
  - it brings the workpiece closer to its final dimension
- Final cutting (Remove last layer)
  - ensures a smooth surface finish & precise dimension

types of breaching operation

- pull Broaching
  - ↓ longer cuts
- Push Broaching
  - ↓ shorter cuts
  - the Broacher is pushed through the workpiece
- continous Broaching
  - ↓
  - high speed production
  - work is moved continously against the stationary Broaches
- key way

type of machine

- vertical
  - ↓ surface broaching
- Horizontal
  - ↓ internal & surface broaching of small - and medium - size parts
- Continous tunnel broaching Machine
  - ↓ surface broaching

Components of a shaping Machine

- **Worktable** → Support the workpiece in place. Can be moved vertically or horizontally to adjust the position of the workpiece.
- **Ram** → The reciprocating part of the machine that holds the cutting tool, moves back & forth to cut the material in forward stroke & return without cutting.
- **Tool head** → holds the cutting Tool, also can be adjusted to set the depth of the cut & the cutting angle.
- **Cutting tool**
- **Cross rail** → Support the work table & allows for vertical adjustment
- **Feed Mechanism**
- **Column & Base** → houses the mechanism that drives the ram

Mechanism of motion conversion

The shaping machine converts the **rotational motion** (from the motor) → **translation motion** (reciprocating motion of the ram)

* **gear mechanism** → Transfers the motor's rotational energy to the shaping mechanism

* **fly wheel**
stores the rotational energy & maintains a smooth operation by reducing fluctuations in the ram's motion

→ bigger FLYWHEEL is used for higher moment of inertia which stabilizes the motion & handling larger impact forces during the cutting process.

* **Crank & lever system**
converts the rotational motion of the motor & flywheel into a linear motion.

Shapers → Machine tool that uses a reciprocating ~~tool~~ motion for a straight line cut

It's a single point cutting tool

The work piece is stationary, while the cutting tool moves in a straight line back & forth

shapers are ideal for machining flat surfaces.

Types of shapers

- horizontal
  - ↓ heavy cuts
  - commonly used in rail road shops for shaping large components.
- vertical
  - ↓ Internal cutting
  - suitable for die work, metal molds, metal patterns

Adv: Little vibration or chatter

There is two type of conditions → orthogonal shaping / → oblique shaping

Key points

1- cutting Tool Motion

- → The cutting Tool is mounted on a ram.
- → The ram is moved in a ~~cutting~~ reciprocating motion

Forward stroke ↓ Cuts the material at a velocity V

Return stroke ↓ Moves back quickly without cutting the velocity is higher than the cutting stroke.

2- cutting velocity

The velocity is not constant throughout the cutting stroke

- Starts at zero at the begining of the stroke
- Increases to maximum in the middle of the stroke
- gradually decreases back to zero at the end of the stroke

سؤال حلو
معنا بالهوستة

surface 600 × 800 mm

$V_c = 8 m/min$

1 : 4

$f = 2$ mm / double stroke

the clearance = 70 mm

cutting total time?

Total length $= L + C_1 + C_2$

$= 600 + 70 + 70 = 740$ mm

cutting time $= \frac{L}{V} = \frac{740 \text{ mm} \times 60}{8 \text{ m/min} \times 10^3} = 5.55$ sec

Return time $= \frac{\text{cutting time}}{4} = \frac{5.55}{4}$ (From ratio → 4)

total time for one stroke $= t_c + t_R = 6.94$ sec

Total strokes required $= \frac{\text{Width of plate}}{\text{feed}} = \frac{800}{2} = 400$

cutting total time = Total strokes × total time req for one stroke

$= 400 \times 6.94 = 2775$ sec $= 46.25$ min

example 2

$L = 250$ mm

$W = 150$ mm

$\frac{\text{cutting}}{\text{return}} = \frac{3}{2}$

$V_c = 21$ m/min

$f = 2$ mm/stroke

$C = 25$ mm

$d = 4$ mm

find the total machining time & MRR?

$L_{Total} = 250 + 25 + 25 = 300$ mm

$t_c = \frac{L}{V} = \frac{300 \times 10^{-3}}{21 \text{ m}} \times 60 = 0.857$ sec

$t_r = \frac{0.857}{3} \times 2 = 0.571$ sec

Total time $= 0.857 + 0.571 = 1.428$ sec

Total strokes $= \frac{150}{2} = 75$ stroke

Total Time $= 75 \times 1.428 = 107.1$ sec

MRR = w d v

150 × 4 ×

Bonding materials

↓

must be strength, toughness, hardness & temprature resistance to hold the abrasive grains together

XX - A - 36 - L - 5 - V - XX

- XX → Manufacturer's symbol
- A →
  - A: Aluminum oxide
  - SiC: Silicon carbide
  - D: Diamond
- 36 → grit size
  - 10-24 Abrasive (coarse)
  - 30-60 midium
  - 70-180 fine
  - 220-600 very fine
- L → Grade
  - A-H: soft
  - J-P: medium
  - Q-Z: hard
- 5 → structure
  - 1-15 and over
  - dense - open
- V → Bond type
  - V: Versatile
  - S: Silicate
  - E: shallec
  - R: rubber
  - B: resionoid
  - BF: resionoid reinforced
  - O: oxy chloride
  - M: Metalic
- XX → manufacturer factory record

Grinding: material removal by an abrasive bonded grinding wheel rotating with high speed.

Grinding wheel (basic parameters)
- Abrasive material
- grain size
- bonding material → means the substance that hold the abrasive grains.
- wheel grade
- wheel structure.

the surface of the grinding wheel contains →
- Abrasive grains (irregular shapes)
- Wheel porosity (small voids)
- Wear flats
- Metal chips.

two types
- conventional abrasives
  - Aluminum oxides
  - silicon carbides
- superabrasive
  - Diamond
  - Cubic boron nitride (خفض الـ strength تبع الـ diamond)

Aluminum oxides → grinding ferrous & high strength alloys (Knoop hardness ~ 2100)

silicon carbide → grinding aluminum, brass, and stainless steel cast iron & certain ceramics (~ 2500)

cubic boron nitride → grinding hardened steel & aerospace alloys (~5000)

Diamond → grinding ceramics, cemented carbides and glass (~ 7000)

Grain size → size of abrasive particles.
- Fine grains: 250 → softer material & for lapping & superfinishing.
- Coarse grains: 8 → for harder material

Related Abrasive processes

Honing → uses bonded abrasive particles for making round hole

lapping → for production of surface of extreme accuracy & smoothness

super finishing → similar to honing but shorter stroke
- → lower pressure between tool & workpiece
- → lower workspeed
- → smaller grit size

Polishing → removes scratches & burrs using abrasive material attached to a polishing wheel rotating at high speed of around 38 m/min.
- → Abrasive grains are glued to the out side periphery of flexible wheel.

Buffing → similar to polishing but used to form a high luster surface
- → wheels are softer
- → very fine grit size mixed in buffing compound.
- → perform manually.

* The bond holds the abrasive grains together & impact cutting performance.

* Wheel grade : bond strength between abrasive grits, Largely depending on the proportion of the bonded material in the wheel.

Mechanical Energy Processes

- Ultrasonic machining
- Water Jet cutting
- Abrasive water jet cutting
- Abrasive Jet Machining

* conventional machining Vs. non conventional machining

1- contact and tool wear
- in traditional process (conventional machining), there is a contact between the tool & the workpiece, causing to friction & tool wear.
- in non conventional process, there is no contact, tool wear is minimum or not a major concern.

2- material removal rate
- in conventional machining it's limited by the mechanical properties of the material, so struggles with hard-to-cut materials
- non-conventional machining handles difficult to cut materials such as ceramics, fiber reinforced composites - - -

3- work piece motion & shapes
- relative motion between the tool & workpiece is rotary or reciprocating so it is → limited to circular or flat surfaces
- designed specifically to handle these complex shapes

4- complex features
- struggles with machining small cavities, slits, holes
- handles these features

5- cost
- Traditional processes → simple, inexpensive machines"
- non-traditional " → expensive machines & skilled labor.

So, back to mechanical process, material removal is achieved using mechanical energy → applied in a form of
- High frequency vibration
- Kinetic energy of abrasive jet.

we have
- → Ultra sonic machining (USM)
- → Abrasive Jet machining (AJM)
- → Water Jet machining (WJM)

NON-TRADITIONAL PROCESS

A group of processes that don't use a sharp tool instead we use a various techniques like mechanical, chemical electrical & thermal to remove excess material.

purpose: It's used when the conventional tools are not effective.

1- Mechanical energy process
2- electrochemical Machining process
3- Thermal energy process
4- chemical Machining

Why non traditional processes are IMP?

- machine newly developed metals & non metals with special properties
- complex part geometry
- minimize surface damage.

Requirement:

- high hardness & strength
- too flexible or Slender (Delicate) → because it can't withstand the forces in conventional pr.
- complex shapes such as internal & external profiles
- surface finish or tolerance, better,
- Temp. rise or residual stresses are undesirable

Classification of Nontraditional processes → Type of energy used

- **Mechanical** → uses erosion to remove material by high velocity streams of abrasive or fluid
- **chemical** → electrochemical energy to remove material
- **Thermal** → Applies thermal energy, this cause material to melt, vaporize or fuse
- **electrical** → use chemical etchants to remove material

ADV:

- Low capital cost
- suitable for all types of materials
- ~~less vibration~~
- good for difficult to reach areas
- no heat generation
- Cut intricate holes

D.AV

- Low material removal rate (slower)
- particles are embedding in the workpiece affecting the quality
- Accuracy Affected by particles spread.
- ~~Aon~~ Abrasive powder can't be reused

Application

- **glass processing**
  - used for abrading & frosting glass (It's more economical than acid etching & grinding)
- **surface cleaning**
  - removes smears, ceramics & oxide coatings
- **Resistive coating removal**
- **Delicate cleaning**
  - dealing with antique pieces.
- **Semi-conductor machining**

ABRASIVE JET CUTTING

A high-pressure stream of fine-grains abrasives, mixed with air or suitable gas is directed onto the workpiece surface via nozzle.

The material is removed through the erosive action of the abrasive particles.

How it Differs from sandblasting

the grains are finer, offering more control. This allows for precision cutting & is not just for surface cleaning like in sandblast.

primarily used for cutting hard and brittle materials like glass & ceramics, also effective for thin materials & those sensitive to heat.

parameters

- Abrasive
  - Aluminum oxide for brass & Al
  - Silicon carbides for ceramics & stainless steel
  - bicarbonate of soda → teflon
  - glass bed → polishing
- Medium
  - Dry air, N_2, CO_2
- Nozzle
  - Material: Tungesten carbide or Sapphire

factors affecting the MRR

- Type of abrasive
- abrasive grain size
  - smaller grains → Smooth surfaces but lower MRR
  - Larger grains → rough surfaces
- flow rate
- stand off distance
  - optimal distance ensures maximum energy transfer
- nozzle pressure

Abrasive Water Jet Machining

how it works

- A jet of water mixed with tiny abrasive particles to cut materials
- The cutting rate in traditional water jet is low, especially for ductile material
- The presence of the ~~water jet~~ abrasives reduces cutting forces & enabling the machine to cut thick & hard materials

Why AWJM developed?
↓
To cut materials that can't stand high tempratures for stress distortion or metallurgical reasons such as wood & composites and Traditionally difficult to cut materials

Ultrasonic Machining (USM)

- Abrasive partiles mixed with liquid (slurry) & this liquid ~~is a~~ flows between the tool & the work piece in a high velocity, while the Tool vibrates ~~in~~ at low amplitudes & high frequency.
- Tool oscillation is perpendicular to the work surface
- Tool is fed slowly into work

Application →
- hard, brittle materals
- ideal for creating non round holes or holes with curved axes
- coining operations

What is ultrasonic waves? are sound waves with frequency higher than 20,000 Hz

- energy sources (mechanical, electromagnetic, thermal energy) can creat them
- can travel through →
  - gases
  - liquids
  - solids

complete →

WATER JET MACHINING

involves directing in high pressure & velocity to the surface to be machined.
The Kenitic energy of the water jet converted into pressure energy upon striking work piece., the kinetic energy reduced to 0 after impacted

Material removal mechanism

If the local pressure that generated by the water jet exceeds the strength of the workpiece, causes the material to erode & forming cavity on the surface.

↓ small area ↑ high energy density.

* water is the most common fluid used, we can add alcohols, oil --- to improve the fluid characteristics

work piece materia →
- soft metals
- paper
- plastic
- frozen food
- cloth
- wood

WJM not effective for brittle → fracture
Ductile material effective

ADV

- no heat produced
- friendly manufacturing
- flexible cutting
- minimal burr production
- no crushing or burning
- ease of automation

EQUIPMENT

- pump with intensifier
- cutting head → including the nozzle for focusing the water jet & the system for worktable movement to guide the cutting process
- filter unit

* used to cut narrow slits in flat surfaces

Abrasive interaction

- Abrasive slurry contains hard particles suspended in a liquid
- Grit size
  - Larger abrasive particle → more force & higher MRR
  - Smaller particles → less forces & less MRR

Force distribution

↓

As the tool moves down, it impacts abrasive particles with increasing force

→ At the lowest position, maximum force acts on the largest abrasives grits larger than the gap penetrate both the tool & workpiece, depending on their size & hardness of the surface.

* Magnetostrictive tranducers

converts the magnetic energy into ultrasonic vibration
Certain materials, like metal & alloys, change their shape
When exposed to a magnetic field → (magnetostrictive effect)

* Piezoelectric tranducers → more efficient than ↑

converts electric energy into ultrasonic vibration
materials like quartz crystals or ceramics, generate mechanical vibration when electricity is applied to them → piezoelectric effect

→ natural or synthetic single crystals → quartz
→ ceramics (barium titanate) → have strong piezo-electric behaviour
↓
they are better ~~than~~ over crystals
because they are easier to shape by casting, pressing & extruding.

PRINCIPLE OF MACHINING

1- Material Removal Mechanism

material is removed by mirco-chipping or erosion ~~caused~~ caused by abrasive particles, driven by a vibrating tool into the workpiece surface.

the tool is made from softer material than the workpiece is osallated by the booster and sonotrode.

- the vibrating tool forces the abrasive particle in the slurry into a gap between the tool & the workpiece.

The tool starts from its upper position & moves down toward the workpiece.
the tool's speed is zero, but as it moves down, it's speed increased maximum speed at the middle of the stroke

working principle

the tool is fed toward the workpiece(+) in precise & controlled rate(0.2mm/s)
the electrolyte ~~is~~ flows between them to carry away
~~the dissolved metal~~ & maintain the gap
↳ insure not to contact

ensures precision ← the gap remains steady
0.4mm

uniform metal removal

cations → moves toward the cathod
anions → moves toward the anod
electrons moves from the anode to the cathod

the electrolyte not only dissolves metal but also ensures the shape of the tool remains unaffected
(ensures only the workpiece dissolved, while the tool remain unchanged)

the electrolyte flows at high speed 3–30 m/s ?

- wash away the dissolved material
- Avoid clogging of the gap between the tool & the workpiece
- ensures smooth continous machining

MRR

the closer the tool is to the work piece, the faster the metal dissdue.
This is why the gap width is inversly proportional to the rate of material remaval.

ELECTROCHEMICAL MACHINING (ECM)

work piece → anode(+)
tool → cathode (−)

material removal happens through anodic dissolution

the process use electric current to dissolve the material at the anode in a electrolyte

a rapidly flowing electrolyte sperates the tool & the workpiece
- → conducts the current
- → removes heat generated during the process
- → flushes away dissolved material

ECM is simmilar to processes like

electro plating
metal coating are deposite upon the surface of catholically polarized metal
(adding a metal coating to an object using electricity)

electro polishing
Involve anodic dissolution but slower MRR, compared with ECM
(making a metal surface smooth & shiny)

How material is removed?

Material removal hapens because the workpiece is the anode & electrolyte dissolves the metal turn it into tiny particle & mixed with the liquid (electrolyte)

- At the anode (+), metal dissolves into electrolyte as iron ions (Fe^{+2})
- At the cathod (−), hydrogen gas is released

− the flows of the electrons in the circuit drives the movement of the ions in the electrolyte ← How It can be different than the metallic conductors of electricity?

APPLICATION

- High accuracy duplication
  - → produce identical parts repeatedly with high degree of accuracy
- Cavities & HOLES
- Sinking operation
  - → RAM, EDM
- Thin & Brittle materials that ~~are~~ can crak (fracture) under mechanical machining

TWO MOST COMMON PRODUCT of ECM

- turbine/compressor blades
- rifle barrels

require machining of extremely hard metals with certain mechanical specifications
→ stress free grooves
→ complex geometry
→ High repeatability
→ fast machining cycles
→ good surface finishes

ECONOMICS OF ECM

- economical for large production → +50 units
- Multi-tool setup
- faster for large cavities → faster than EDM

ECM IMP. COMPONENT

1- POWER

→ the power needed to operate the ECM, supply the electric potential difference needed
→ the current density must be high
→ the gap between the tool & workpiece must be low, for higher accuracy, the voltage must be low to avoid short circuit.

2. Electrolyte circulation system

- the electrolyte must flow in high speed → to insure a good removal of dissolved material & heat.
- pump, filter, reservior, sludge removal system & treatment units
- electrolyte stores in a tank

3. CONTROL SYSTEM

VOLTAGE ← CONTROL SYSTEM → Temprature
↓
Electrolyte Pressure

the CURRENT DEPEND ON THESE PARAMETERS & the feed RATE

ADV

- no cutting force
- no heat generation affected zone
- high surface finish & accuracy
- Relatively fast
- no tool wear
- machine hard materials

D. ADV

- expensive (high cost)
- electrolyte issues
- space requirements
- energy consumption
- Material limitation → deals with electrically conductive material

* Application : grinding hard materials

- Tungsten carbide cutting tool
- fragile component → hypodermic needles

Electro Chemical Deburring (ECD)

is a specialized application of ECM
design to remove burrs or round sharp corners
in metal parts produced by conventional machining (Drilling)

Electrochemical grinding (ECG)

special form of ECM
It's combination of electrochemical Machining & conventional grinding.

the grinding wheel with conductive bond material acts → cathode
& work alongside the electrolyte to remove material from
the workpiece (anode)

1- grinding wheel
made of metal bond combined with abrasive particles

2- non-conductive abrasive particles
acts → spacers between the grinding wheel & the workpiece
& maintain a constant gap.

3- electrolyte flow
↳ flows through the gap

Material Removal Mechanism

Material is removed by combination of

- electrochemical dissolution
  removes → 90%
- Abrasive action
  the grinding wheel removes any residual material

limitation

↳ due to ~~Small~~ electric field effects, inside corner & radii smaller than 0.25 mm hard to achieve

* EDM tooling
- electrode materials
  - ↳ graphite
  - ↳ metal alloys
- electrode wear

↓

the electrode wear out during Machining requiring multiple tool.s for large & ~~small~~ complex cavities

ADvantages	Dis-Advantages
• good for maching intricate shapes	• slow process MRR is slower than the traditional Methods
• No physical contact	• Tool wear
• versatility ↓ hard materials & fragile parts	• surface finish ↳ often required post-processing to enhace the surface finish

Applications

- ↓ Mold & Dies
- ↓ small, delicate parts
- ↓ Machining holes at acute angles
- ↓ Exotic & hard to maching materials

THERMAL ENERGY PROCESSES

- electric discharge machining
- electric discharge wire cutting
- electron beam machining
- Laser beam machining
- Plasma arc maching

* Thermal energy processes are machining processes where high local Temprature are used to remove material by fusion or melting ⟶ turning into gas.
* can be used only on electrically conducting work material
* surface finish is often poor, requiring additional process

ELECTRIC DISCHARGE MACHINING (EDM)

know (sparks errosion machining)

removes material by eroding it through electrical discharges (sparks) between the tool & the work piece

⟶ deal with material that are electrical conductors

setup ⟶ the tool (electrode) ⟹ −ve terminal (cathode)
↳ the work piece ⟹ +ve terminal (anode)

Both are submerged in dielectric fluid ⟶ cools the material & removes debris

small gap is maintain between the tool & the work piece

when voltage is applied ⟶ sparks are disscharge across the fluid
↓
melt & vaporize material ⟵ generating heat

- each spark erodes a tiny amount of metal
- the gap between the tool & the work piece is controlled by numerical control (NC) system to maintain precision

prameters

1- current ⟶ generating current ⟶ more powerful sparks
↳ this can creat larger craters & result in a rougher surface finish

2- frequency

Increasing the freq. ⟶ smaller craters & smooth surface Finish but slows down the MRR.

MRR directly propotioned to the current

Application

- Die & Mold Making
- Intricate Designs
- Internal cavities

ADV

- precision
- no physical contact
- versatile → Hard & conductive material

Limitation

- requires pilot holes (pre-drilled hole)
- wire use → disposal & increasing the operation cost
- Slow cutting

WIRE EDM (WEDM)

Special form of EDM
that use a small-diameter wire ~~to~~ electrode to cut a pricise path (kerf) in a conductive workpiece.

- commonly used for production intricate shapes & small details

Component:

- wire electrode
  - Made of Bass, copper or tungsten
- Dielectric fluid
  - flows continuosly to cool process & remove debris

* Process

The wire electrode travels along ~~the~~ programmed path (like a Bandsaw), while cutting the material with sparks generated by electrical discharges

cutting Mechanism

↳ the wire does not touch the work piece instead use spark erosion to melt ~~the~~ vaporize the material

- can cut plates up to 12 inches thick
- pricise cut for internal cavities (requires a pilot hole for threading the wire)
- Can achieve high accuracy for intricate & delicate designs
- 0.005 inches → thin of the wire
- the wire is strong and tough but only used once (Disposable)
- The Korf (gap left by the wire) is small

ADV

- non contact process.
- high precision
- Material versatility.

Design for considration

- surface requirement
  - use on dull, unpolished surfaces to maximize laser absorption
- geometry limitation
  - Avoid sharp corners as deep cuts may produce tapered surfaces

Plasma arc Cutting (PAC)

uses a plasma stream operating at very high tempratures to cut metal by melting.

LASEM BEAM MACHINING (LBM)

A non contact thermal process that uses highly focused laser beam to remove material by vaporization or ablation

- A laser generates a concentrated beam of light energy, which is directed onto the workpiece.

Key component

- Laser source
  - convert the electrical energy into light energy
    - CO_2 laser: Efficient, high power
    - Nd:YAG Laser: Solid state lasers emitting light with high precision
- Reflecting miror
- Les
  - focuses the laser beam onto the workpiece for a pricise machining
- Dielectric fluid
  - Cool the material & remove debris

~~Workpie~~ MR mechanism

Heat from the laser beam causes vaporization or melting of material.

- Can replace a conventional process like punching or shearing

IMP. factors for workpiece material

- low Reflectivity
- Low thermal conductivity
- Low specific Heat.
- low latent heat of Melting / evaporation

~~#~~Application

- cutting & Drilling
  - sharp corners
- welding
- localized heat treatment
- Marking & engraving