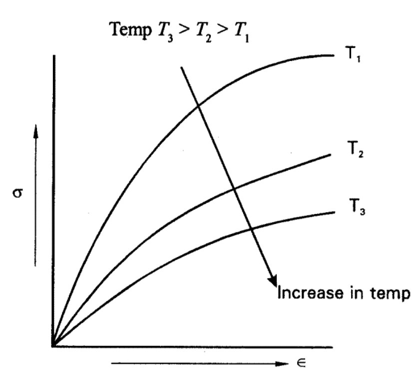
# PARAMETERS AFFECTING MECHANICAL WORKING PROCESSES

The following parameters influence the Mechanical Working Process:

i) Temperature of Metal
ii) Strain Rate
iii) Friction
iv) Nature of Forces
v) Metal Structure

**i)Temperature of Metal**

All metals posses hardness and strength. As a result of this one has to apply sufficient load to deform the metal. If the metal is heated to a higher temperature, the strength and hardness are reduced and the ductility is enhanced.
The metal can be deformed easily.
As the temperature of the metal is increased the metal can be deformed more easily.
The metal becomes softer.
The same is exhibited graphically as shown.
As the temperature is increased the stress strain curve shows reduced slope or it will have gentle slope.



Variation of Stress-Strain w.r.t temperature
It can be seen that T3 is higher than other two temperatures.
Thus it has decreased the yield strength of the material and the slope of the curve is gentle.

Hence, one can work the material at T3 temperature easily.

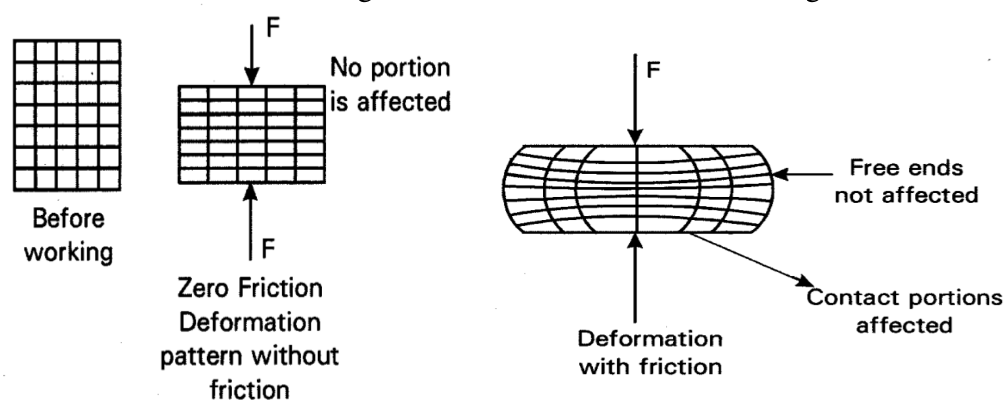
**ii) Strain Rate**

Strain rate is the rate at which strain is induced in the metal.
It is also a measure of rate of deformation, as the metal is being worked at a known speed. Viz., the rate at which deformation is taking place.
If V= Deformation Velocity
t= Instantaneous thickness of the metal
then strain rate, $\acute{\varepsilon} = V/t$

As strain rate increases, the metal becomes hardened and flow stress increases.
An increase in the strain rate increases the strain hardening in the metal.
The metal temperature required for deformation increases with increase in strain hardening.

**iii) Friction**

Friction is the resistance offered by one surface against the other whenever there is a relative motion between the two surfaces. More work is to be done in overcoming it.
In metal working process also, friction place a very important role. Friction alters the metal deformation pattern.Deformation tends to be non uniform. Heat is generated at the contact surface.Metal may stick to the tool face.Plastic flow occurs rather than sliding. Load required for deformation increases Loss of energy occurs. Die and tool wears out faster. The surface layers become irregular and develops microcracks.
Consider a specimen marked with vertical and horizontal grids as shown. Let it be subjected to compressive load and deformed with and without friction.
The deformation pattern is observed after the test.
It can be clearly seen from the figure the effect of friction on metal deformation pattern.
When there is no friction the deformation will be uniform.
The vertical and horizontal grids will remain uniform and straight.

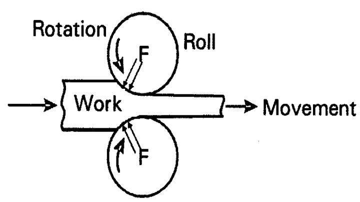



***Effect of friction on metal deformation***

When there is friction, metal flow is affected to a large extent.
The vertical grids and horizontal grids are bent as shown.
Free ends are not affected whereas the contact surfaces are held back causing bent pattern in the metal flow.
Metal flow is affected to a large extent at the contact surface as compared to the free end.
It has been well established that for cold rolling the coefficient friction is around 0.1 and for hot rolling it is around 0.6.
Friction is a natural phenomenon and has to be controlled in mechanical working process for smooth and uniform deformation of the metal.This can be achieved to a great extent by use of lubricants.A lubricant prevents or reduces unnecessary rubbing of the surfaces and controls surface finish of the components.In general solid lubricants such as glass, MoS2,graphite, lead,Teflon,polyethylene, BoN2 are used for the purpose.
Basically they have low shear strength property.

**iv)Nature of Forces**

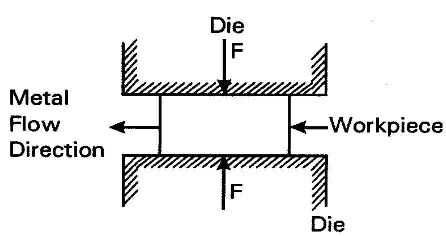
The type of forces influences the deformation process.Based on the type of Mechanical working process the nature of forces is automatically fixed. The nature of forces influence the metal flow and the process as such.
The same is shown in the following figures:




***Rolling***

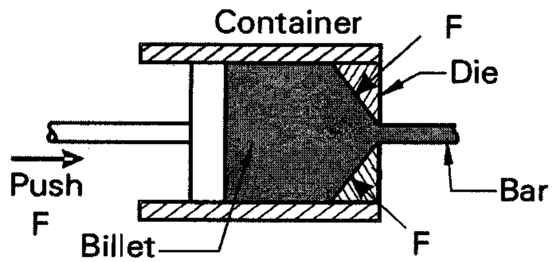
In Rolling the flow of metal is at right angles to the applied load. This is Compressive Load.
In rolling process there is a direct compressive load or stress acting on the metal (work).
The direction of load will be acting at right angles to the flow of work.

In open die forging process direct compressive load or stress will be acting on the metal and the direction of the metal flow will be at right angles to the applied load.
In Forging the flow of metal is at right angles to the applied load.
This is Compressive Load



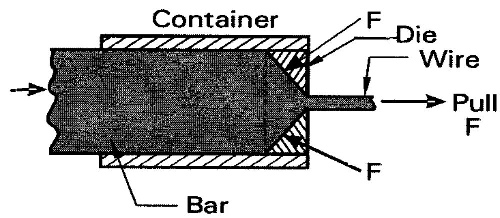

***Open die Forging***

In extrusion and wire drawing processes Indirect compressive load or stress will be acting. The primary applied force (push or pull force) is to cause metal to move.Indirect compressive force will be developed as a result of reaction of the work piece and the die surface.




Extrusion

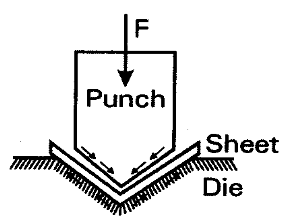
In Extrusion the flow of metal is at an angle to the applied load. The metal experiences the normal load at the inclined die surface. This is Indirect Compressive Load




Wire drawing

In Wire Drawing as in Extrusion the flow of metal is at an angles to the applied load. The metal experiences the normal load at the inclined die surface.
This is Indirect Compressive Load
In bending operation a sheet is subjected to bending action where in the sheet is bent into an arc of a circle or through an angle.

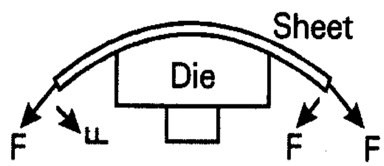
The sheet is subjected to deformation by using a punch and a die.
The sheet experiences both tensile and compressive stresses on either side of the sheet and it is similar to a three point bending.
The required shape is obtained




Bending

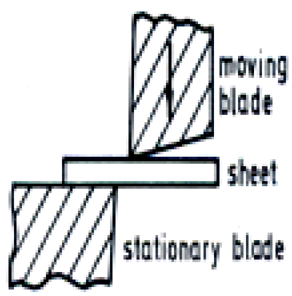
In Bending, The metal experiences Compressive force at the inside portion near the punch and tensile force at the outside portion near the die. Both tensile and compressive force are acting at the same time. This is Bending Stress.
In Stretch Forming operation metal sheet is placed on a contoured die of required shape and pulled outward along the die surface. This will result in pulling force being induced in the sheet.

The sheet is also pulled inward towards the center of the arc of the die.By repeated pulling of the sheet the required load beyond the elastic limit is imposed on the sheet and the sheet will finally takes the shape of the die.
This type of deformation is used for producing large components having large radius of contour as in aircraft body or space craft structure or large dish type of object as in solar panels or reflectors etc.,



Stretch forming

In Stretch Forming the flow of metal is along the direction of the pulling force applied . The metal experiences pulling force towards the center of the arc also.This is Pulling or Tensile force.In shearing a metal sheet is subjected to cutting action under the influence of two sharp blades. It is similar to a cutting of a sheet of paper using a scissors or punching of paper sheet using a punch. The force applied exceeds the yield load and reaches the ultimate load required for failure of the sheet.Using shear operation,various contours in the sheet can be created. The cut sheet is used for other operations like bending or stretching or coining etc.,



Shearing

In Shearing the forces will be acting parallel to the cross section of the metal The metal experiences tangential force at the surface.
This is Shear force or Tangential force.

**Hydrostatic Force :**

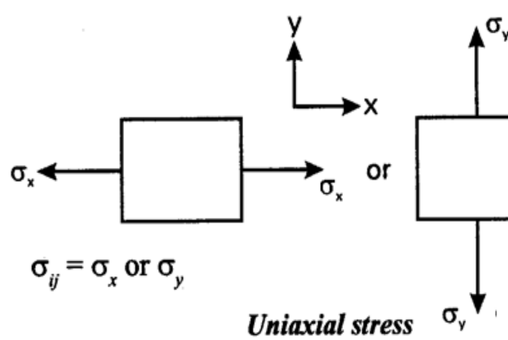
It is a system of forces acting on the body whose magnitude is the same in all the three direction. Its effect on the mechanical working is to assist uniform deformation.

**v) Metal structure**

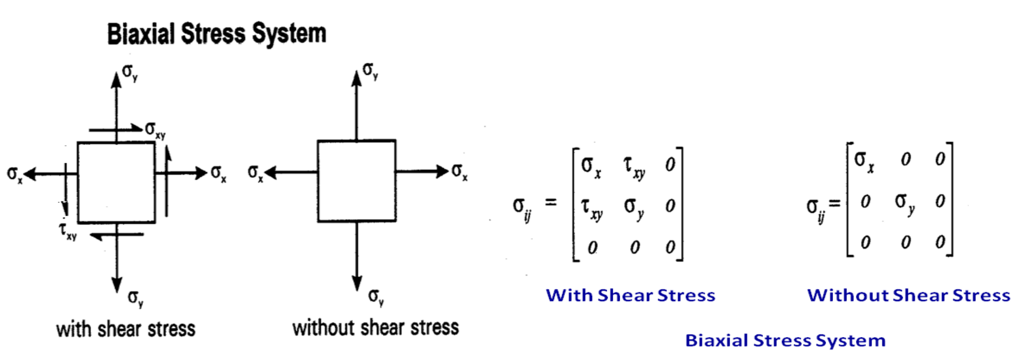
The arrangements of atoms in the crystal structure of the metal influences the mechanical working process.

The metal could have Cubic or FCC or BCC or HCP structure. FCC structure undergoes more strain hardening and hence very difficult to mechanically work. HCP structure undergo less strain hardening  and hence easy to mechanically work. BCC structure shows strain hardening in between that of FCC and HCP and  hence it can be mechanically worked with some difficulty.Grain structure also influences metal working process.Coarse grains can be easily worked or deformed as    compared to fine grain structure.This may be due to the fact that  coarse grains can accommodate more dislocation movement as compared to fine grains.Fine grains strain harden faster than coarse grains.

**Stress System:**




In uniaxial stress system the two stresses σx and σy are principal stresses since there are no shear stresses. Hence the planes on which they are acting are the principal planes. We can define  Principal planes are the planes on which there are no shear stresses.Principal stresses are the stresses acting on the principal planes.



**For biaxial Stress System**

$$\sigma_{ij} = \begin{bmatrix} \sigma_x & o \\ o & \sigma_y \end{bmatrix} \text{ is } \begin{bmatrix} \sigma_1 & o \\ o & \sigma_2 \end{bmatrix}$$

**Principal Stresses**

$$\sigma_1 = \sigma_x$$

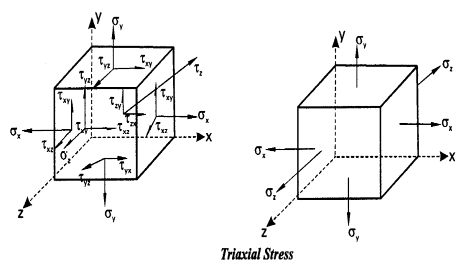
$$\sigma_2 = \sigma_y$$

ii) In Biaxial stress system when only σx and σy are acting without shear stress then they are the Principal Stresses.

**Triaxial Stress System**

In matrix form it is written as

$$\sigma_{ij} \text{ or } \tau_{ij} = \begin{bmatrix} \sigma_x & \tau_{xy} & \tau_{xz} \\ \tau_{yx} & \sigma_y & \tau_{yz} \\ \tau_{zx} & \tau_{zy} & \sigma_z \end{bmatrix}$$




With shear stresses

Without shear stresses

**With Shear Stress**

$$\sigma_{ij} = \begin{bmatrix} \sigma_x & \tau_{xy} & \tau_{xz} \\ \tau_{yx} & \sigma_y & \tau_{yz} \\ \tau_{zx} & \tau_{zy} & \sigma_z \end{bmatrix} \qquad \begin{aligned} \tau_{xy} &= \tau_{yx} \\ \tau_{yz} &= \tau_{zy} \\ \tau_{zx} &= \tau_{xz} \end{aligned}$$

**Without Shear Stress**

$$\sigma_{ij} = \begin{bmatrix} \sigma_x & o & o \\ o & \sigma_y & o \\ o & o & \sigma_z \end{bmatrix}$$

$\sigma_{ij}$ represents the state of the stress in a matrix form.

$$\left.\begin{aligned} \tau_{xy} &= \tau_{yx} \\ \tau_{yz} &= \tau_{zy} \\ \tau_{zx} &= \tau_{xz} \end{aligned}\right\} \text{ are complimentary Shear Stresses}$$

iii) In triaxial stress system when only σx, σy and σz are acting on the planes without any shear stresses then they are the principal stresses.