A.Vinodh Kumar 302
M.Yedukondalu -10318
A.PRAVEEN
M.Tech

→ Deformation Processes in manufacturing are operations that result in changes in a shape due to plastic deformation of the material when subjected to force by various tools and dies.

→ Deformation may be classified by one of the following!
Temperature, size or type of operation.

→ when Temperature is used for classification, a deformation Process may be hot (or) cold.

→ Types of Deformation Process are as follows!
(i) Rolling (ii) Forging (iii) Extrusion iv) Drawing.

→ To improve the Properties of the metal and to Produce a new shape, shaping operations are frequently used. it referred as mechanical working Processes.

→ mechanical working of a metal is defined as plastic deformati[on] Performed to change dimensions, Properties, surface condition by means of mechanical pressure.

→ mechanical working of metals is classified into hot working and cold working depending on temperature.

mechanical working of metals

- Hot working (Above Recrystallization Temp.)
  - → Rolling
  - → Drawing
  - → Piercing
  - → Spinning
  - → Extending
  - → Forging
- cold working Below Recrystallization Temp.
  - → Rolling
  - → Forging
  - → Drawing
  - → Bending
  - → Spinning
  - → Squeezing
  - → Peering
  - → sizing, Coining, Hobbing.

* when the atoms reach a certain higher energy level, the new crystals start forming which is termed as "Recrystallization".

* Recrystallization Temperature is the minimum temperature at which complete recrystallization of a cold worked metal occurs within a specific Time.

Hot working :-

→ plastic deformation of metals above the recrystallization temperature, but below the melting is known as hot working of metals.

→ Hot working processes change in grain structure which impro mechanical properties such as ductility, toughness, resistance to shock loads and vibration.

Advantages :-

1. At a higher Temperature. The material would have higher ductility
2. hot working requires less force to achieve deformation.
3. The process is quick and economical
4. These products giving better mechanical properties.
5. NO strain hardening taking place.

Disadvantages :-

1. The cost of tooling and handling are very high.
2. dimensional accuracy is hard and it is difficult to achieve.
3. Poor surface finish due to scale formation and oxidation.
4. Reliability of the tools used is reduced.

Cold working

→ plastic deformation of metals below the recrystallization Temp. is known as cold working.

→ cold working needs greater pressures than for hot working and severe stresses are set up inside the metal.

Advantages :-

1. mechanical properties of the products such as hardness and strength are increased.
2. The cold products do not require any other surface finish operations
3. Better dimensional accuracy is achieved.
4. It is easier to handle cold parts and is economical

Disadvantages :-

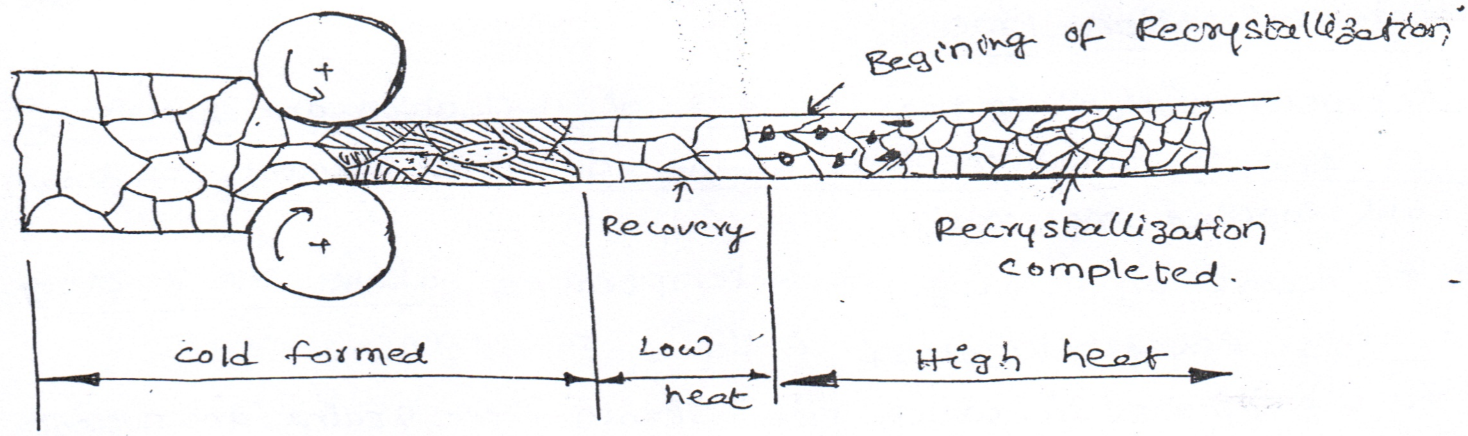
1. Cold working process is limited to ductile metals only.
2. High power and heavier equipments are required.
3. It requires additional heat treatment processing of metals
4. distortion of grain structure is created.

Recrystallization Process :-

* Recrystallization is the process of nucleation and growth of new crystals which replace all the deformed crystals of the cold worked material.
* It occurs on heating at a temperature above the recovery range. Recrystallization follows recovery.
* It is a process in which new strain free grains are nucleate and grow until they have consumed all the work hardened materl.
* New grains having a low dislocation density appear as a result of recrystallization and the hardness and strength of the material are reduced while ductility increases.
* Recrystallization is a function of time because it involves diffusion movement and exchange of atoms across grain boundaries.
* The effects on recrystallization of temperature, of time and of reduction in the thickness or height of the workpiece by cold working are as follows.

1. For const. amount of deformation by cold working the time required for crystallization to occur, decreases with increasing temperature.
2. The greater amount of deformation, the smaller the grain size during recrystallization, this effect is a common method of converting a coarse grained structure to a finer grained structure and hence improved properties.
3. An isotropy due to prefered orientation usually occured after recrystallization. to store isotropy a temperature higher than that required for recrystallization may be necessary.

* The start of the recrystallization process can be detected by x-ray examination of the microstructure, by hardness and other mechanical tests.
* The recrystallization temperature is a function of the type of metal (or) alloy, the purity of the metal, the amount of initial deformation, the grain size annealing time and amount of recovery.



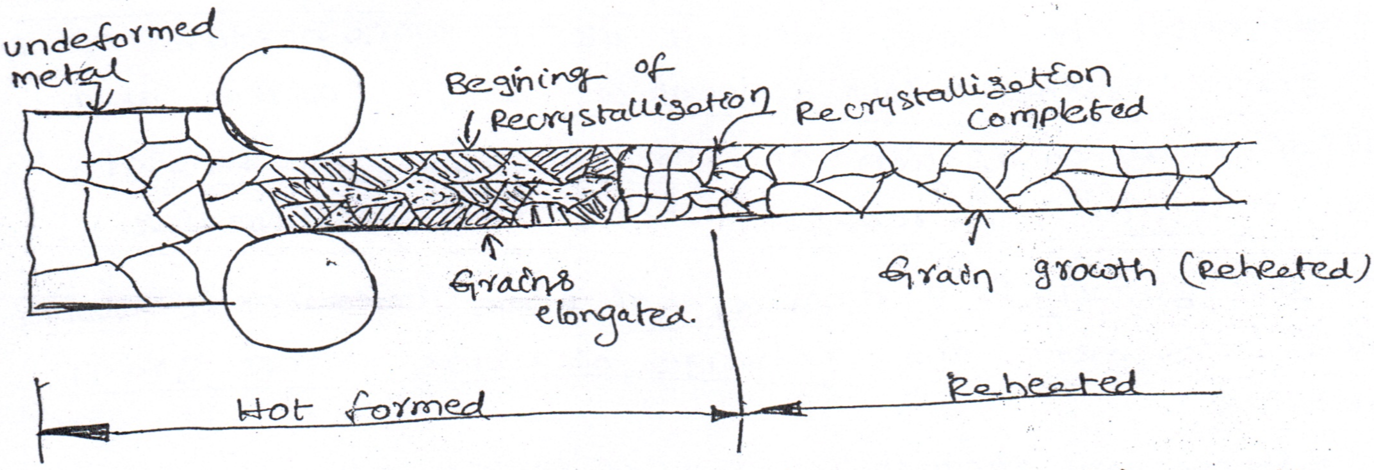


Fig: Diagrams for both cold working and hot working on the microstructure of cast metals.

Grain growth on metals:-

* In hot working, The Process may be carried above the recrystallization Temp. with (or) without actual heating.
Ex:- For lead and Tin, The recrystallization Temp. is below the room Temp. and hence working of metals at room Temp. is hot working.
lly steels, The recrystallization Temp. is 1000'c and working below That temperature is still cold working.
* In hot working, The Temp. at which the working is completed is important since any extra heat left after working will result in The grain growth, Thus giving poor mechanical properties.
* The effect of Temperature after completion in hot working will effect the grain growth.
* In simple heating Process, The grains starts growing after The metal crosses The recrystallization Temp.
* when it is cooled without any hot working The final grain size would be larger than The simple heating.

* After heating when the metal is worked because of recrystallization the grain size is reduced. This is due to the working of metal gives rise to a larger number of new crystals is formed.
* but it is occured above the recrystallization temp. The grains
* starts increasing and finally we can get coarse grain size. This increase in size of the grains occured by joining grains and is a function of time and temperature.

* If hot working is completed just above the recrystallization temp. The resultant grain size would be fine. This is shown in the following diagram.

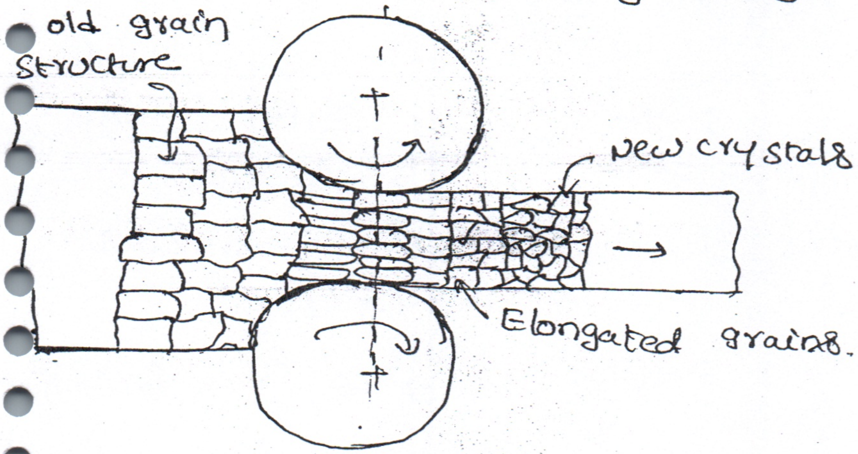


fig:- Grain ~~Refinement~~ Reformation in hot rolling operation.

* Grain growth lowers the energy of the solid because surface energy is associated with grain boundaries.
* Grain size affects the surface appearance of the metal.
* An increase in temperature enhances the thermal vibration of the atoms, which in turn facilitates the transfer of atoms across the interface from small to large grains.
* The process of grain growth depends on the following.
  - (i) Annealing temperature and time
  - ii) Rate of heating
  - iii) Insoluble impurities
  - iv) Alloying elements
  - v) Rate of cooling
  - vi) Extent of initial deformation.

→ comparision (or) Differences in the Properties of cold worked Parts and hot worked Parts.

Hot working	Cold working
1. The working Temperature is above the recrystallization Temperature. In hot working there is grain refinement due to breaking up of grains into smaller crystalls.	1. The working Temp. is below the recrystallization Temp. In cold working, grain refinement is not Possible.
2. Surface finish obtained is Poor	2. Better Surface finish is obtained.
3. No need of intermediate annealing.	3. It Requires Intermediate Annealing.
4. Contamination Problems are more.	4. Contamination problems are minimized.
5. Cracks and blow holes are welded.	5. Propagation of Crack formation is more.
6. Sealing and oxidation of the surface occurs at high Temperature.	6. Process is carried at low Temp. There is no Problem of scaling
7. There is no Problem of development of Residual Stresses.	7. undesirable Residual stresses may be Produced.
8. Structure and Properties of hot worked metals are generally not so uniform over the cross section.	8. Structure and Properties are generally uniform over the cross section of metals.
9. Impurities are squeezed into fibres and are distributed throughout the workpiece.	9. There is no such Problem.

* Rolling is a very economical Process for Producing large volumes of materials with constant cross section.
* Rolling is a Process where the metal is compressed between two rotating rolls for reducing its cross sectional area.
* This is one of the most widely used of all the metal working Processes, because of its higher Productivity and low cost.
* Rolling would be able to Produce components having constant cross section throughout its length.
* many shapes such as I, T, L but not very complex shapes. it is also possiable to Produce special sections such as railway wagon wheels by rolling individual pieces.

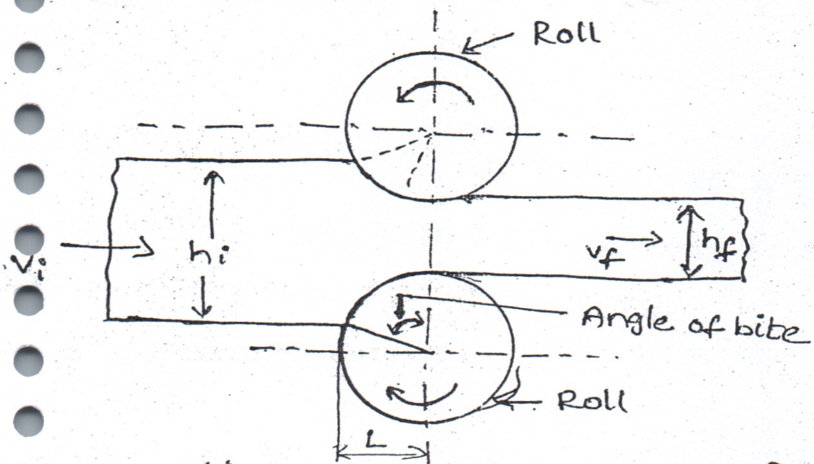


diagram of the Rolling Process.

* Rolling is a hot working Process unless specified as cold working
* the metal is taken into rolls by friction and compressed to obtain the final shape.
* The Thickness of the metal that can be drawn into rolls depend on the roughness of the roll surface. Rougher rolls would be able to achieve greater reduction than smoother rolls.
* The reduction that could be achieved with a given set of rolls is designated as the "angle of bite". This depends on the type of rolling and condition of rolls.
* when the metal enters the rolls, the surface speed of rolls is higher than that of the incoming metal, whereas the metal veloci at the exit is higher than that of the surface speed of rolls.
* The Area of the cross section gets decreased, the metal leaving the rolls would be at a higher velocity than when it entered

* The volume of the metal that enters the rolling stand should be the same as that leaving it except in initial passes when some loss due to filling of voids and cavities in ingot.
* The pressure on rolls gradually builds up from the entry to the neutral point where it is highest and then decreases till it reaches the exit.
* The average roll pressure can be depend on the contact length. Smaller contact lengths means lesser friction forces acting. it can be achieved by reducing roll diameter since, smaller rolls would have less contact length than larger rolls for same reduction.
* The smaller rolls are used for larger reductions. The smaller rolls would not have enough rigidity to support. Hence back up rolls are attached to the small rolls to provide the necessary rigidity.

Rolling load :-

* Rolling load requires the understanding of plasticity theory.
* The pressure on rolls starts from the entry point and continues to build up till the neutral point. similarly the exit pressure is zero at the exit point and increases towards the neutral point.
* The total rolling load is distributed over the arc of contact on the typical mill pressure distribution.
* The total rolling load can be assumed to be concentrated at a point along the arc of contact at a distance (L) from the line of centre of the Rolls.
* The following expressions are valid for rolling of flat surfaces.

The Rolling force is given by,

F = contact area x average contact stress.

$$F = L w P_{av}$$

∴ P_{av} depends upon the ratio of $\left(\frac{h}{L}\right)$

$$P_{av} = \sigma_{fm}\left[1 - \frac{\mu L}{2 h_{av}}\right].$$

∴ Roll force the becomes

$$F = L w \sigma_{fm}\left[1 - \frac{\mu L}{2 h_{av}}\right]$$

where

L = length of contact.

w = width of strip.

P_{av} = contact stress.

μ = co-efficient of friction.

h_{av} = average height of w/p.

σ_{fm} = mean flow stress.

Roll Torque :-

The torque required to rotate the rolls is calculated by assuming that the rolling force acts in the middle of arc of contact. As there are two rolls to be driven, multiply by 2 in torque equation.

Torque per roll $T = \frac{FL}{2}$

Total Torque $T = 2 \times \frac{FL}{2} = FL.$

The Power required in deforming the metal as it flows through the roll gap.

Power Required per roll P = Torque x Angular Speed of roll.

$$P = \frac{T \times \omega}{1000} \text{ kw.}$$

where T = Torque = FL

$\omega = \frac{2\pi N}{60}.$

$\therefore$ Power Required/roll $P = \frac{2FL\pi N}{60,000}$ kw.

Total Power Required $P = \frac{2FL\pi N}{60,000}$ kw

* The Power needed to overcome friction in the bearings and the pinions must be determined seperately.

Types of Rolling mills :-

* The arrangement of rolls in a rolling mill, also called "Rolling Stand".
* Depending on the application the various number of Possible Rolling stands are given by the number of rolls employed.

These are :

1. Two-high non reversing mill
2. 2-high Reversible mill
3. 3-high Rolling stand
4. 4-high Rolling stand
5. cluster Rolling mill
6. Planetary Rolling mill.

1. 2-high non-Reversing mill :-

* It is the simplest and most common arrangement.
* In This, the rolls always move in only one direction.
* The opening between rolls can be easily adjusted.

2. 2-high Reversing mill :-

* In This Rolling mill, The direction of roll rotation can be reversed.
* This type of Stand is Particularly useful in reducing The handling of The hot metal in between the rolling Passes.
* When all The metal has reached The Right side, The direction of The rolls reversed and The metal is allowed to enter into The next Pass.
* These Stands are more expensive compared to the non-reversible type because of the reversible drive needed.

3. 3-high Rolling Stand :-

* It is used for rolling of two continues Passes in a rolling sequence without reversing The drives.
* After all The metal has Passed Through The bottom roll set, The end of the metal is entered into The other Set of The rolls for The next Pass.
* It requires less costly motive Power.
* It is less expensive.
* This mill is mostley used for rolling structural steel shapes like I-beams, angles and channels.

4. 4-high Rolling Stand :-

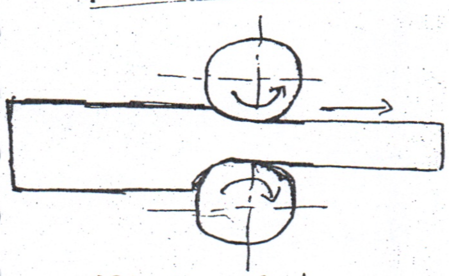
* It is essentially a 2-high rolling mill, but with small sized rolls.
* The other two rolls are the backup rolls for Providing The necessary rigidity to the Small rolls.
* It will gives high strength and rigidity.
* Large decrease in Power can be achieved.

5. cluster Rolling mill :-

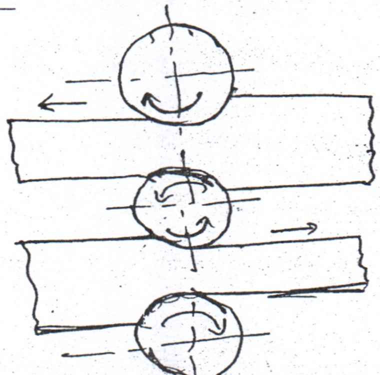
* This mill can gives a better back up can be Provided to the small rolls with a cluster arrangement of rolls.
* It requires large reduction, a number of free rotating wheels instead of a single small roll, are fixed to a large back up roll in the planetary rolling mill.
* close tolerance can be achieved.
* very Thin sheets can be rolled easily.

6. Planetory Rolling mill :-

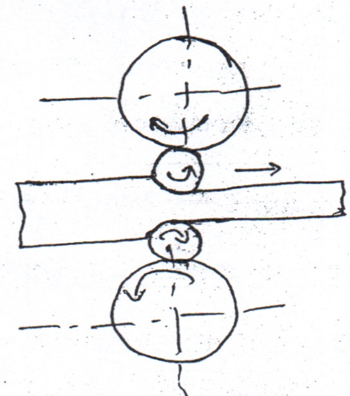
* For large reduction we are using this type of Rolling mill.
* In this arrangement a number of free rotating wheels instead of a single small roll are fixed to a large back up roll.
* It Provides a Pair of Powerful rolls which forces the slab into the roll gap.
* Brittle materials which can not be hot rolled. can also handled by a planetary mill.



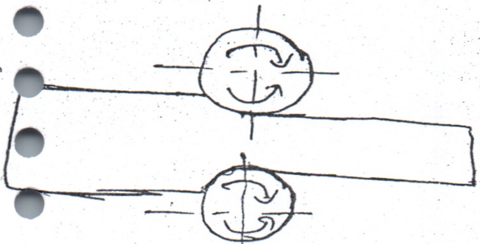
(a) 2-High



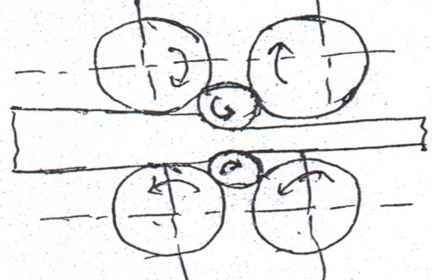
(c) 3-High.



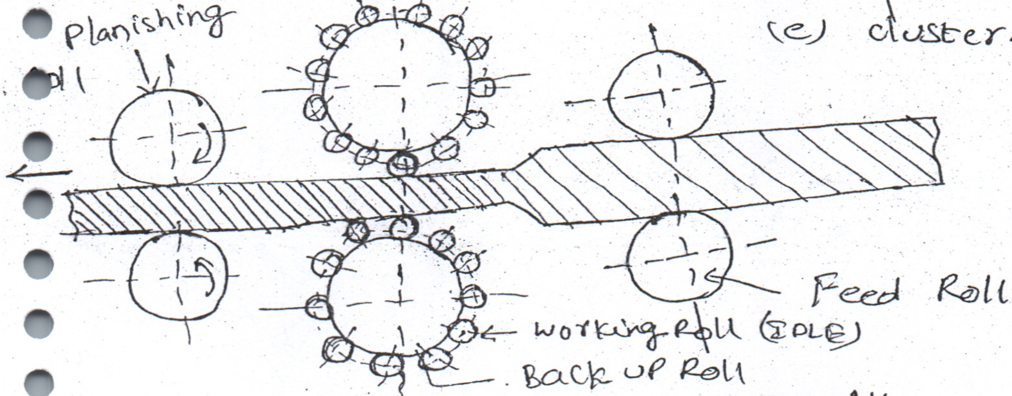
(d) 4-High.



(b) 2-High Reversible



(e) cluster.



6. planetory Rolling mill

Defects in rolling :-

* The various defects in rolling Process are classified below.
    1. Surface defects
    2. Structural defects.

1. Surface defects :-

* The surface defects can be resulted from.
    - inclusions and impurities in the material.
    - Scale, rust, dirt, Roll marks
    - other causes like Prior treatment and working of the material
* In hot rolling blooms, billets and slabs in which the surface is Pre conditioned by removing scale.

2. Structural defects :-

These defects distort (or) affect the integrity of the rolled Product

(i) wavy edges :-

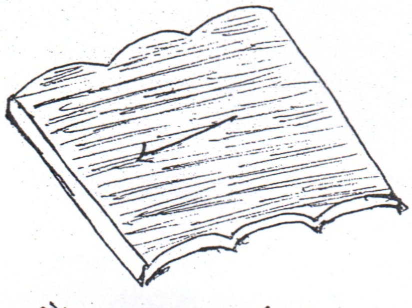
* These are caused by bending of the rolls ; the edges of the strip are thinner than the centre.
* Because the edges elongate more than the centre and are restrained from expanding freely, They buckle.

(ii) Sipper cracks & edge cracks :-

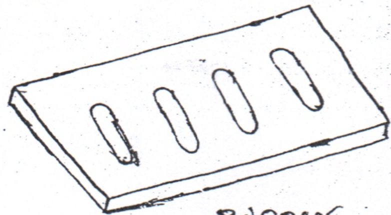
* Sipper cracks are in the centre of strip.
* Edge cracks are in the edges due to low ductility.

(iii) Alligatoring :-

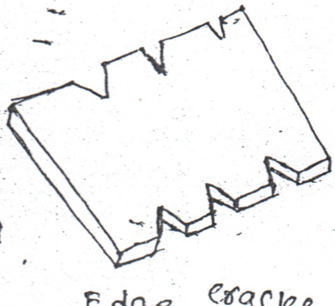
* Alligatoring is a complex phenomenon that results from in homogeneous deformation of the material during rolling. because of resistence forces.



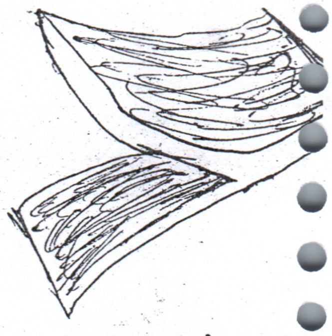
(i) wavy edges



(ii) Sipper cracks



Edge cracks.



(iii) Alligatoring.

Types of Rolling operations :- (or) Types of Rolled Products

* In addition to flat rolling, various shapes (or) Products can be Produced by different rolling operations.
* Straight and long structural shapes, such as solid bars, channels, I-beams and rail road rails, are Rolled by Passing the stock through a set specifically designed rolls.

1. Ring Rolling :-

* In the Ring rolling Process, a thick rolling ring is expanded into a large diameter ring with a reduced cross section.
* The ring is placed b/n two rolls, one of which is driven and its thickness is reduced by bringing the rolls closer together as they rotate.
* The volume of the ring remains constant during deformation, the reduction in thickness is compensated by an increase in the ring's diameter.
* The ring-shaped blank may be Produced by means as by cutting from a plate by piercing or by cutting a thick walled pipe.
* The driving Roll A is fixed but free to rotate on its axis.
* The Pressure Roll B is made to approach Roll A as to grip the ring between A and B.
* when the ring is gripped, it is caused to rotate, at the same time it is continuously reduced in thickness. and the required diameter is obtained.
* In order to get a circular ring is rolled, a pair of guide rolls correctly positioned must be used.
* Applications of Ring Rolling are large rings for rockets and turbines, Gear wheel rims, ball bearing and Roller bearing races, Flanges and Reinforcing rings for Pipes.
* Ring Rolling can be carried out at room (or) at elevated Temp. depending on the size, strength, ductility of the workpiece material.

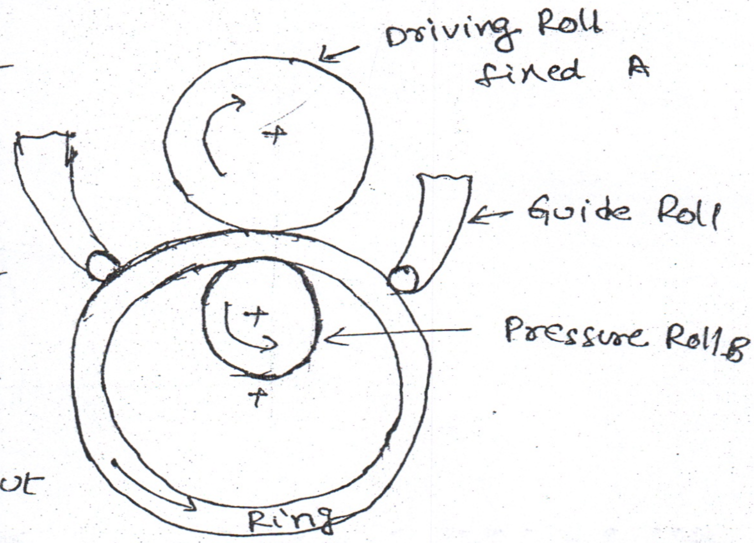
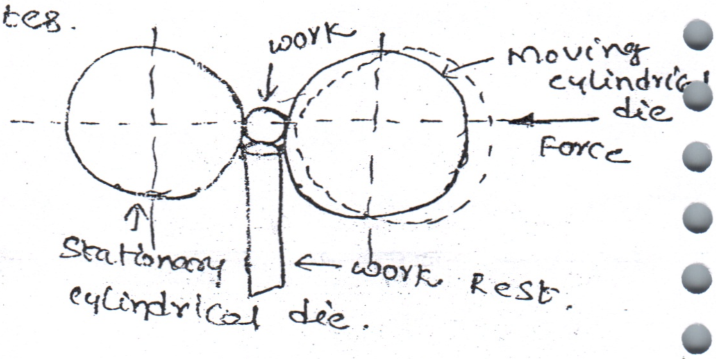


Fig: Ring Rolling

Thread Rolling:-

* The Thread rolling Process is a cold forming Process by which straight (or) tapered threads are formed on round rods, by passing them between dies.
* Threads are formed on the rod (or) wire with each stroke of a pair of flat reciprocating dies.
* The Products like screws, bolts and similar threaded parts.
* The Process capable of grooves and various gear forms, on other surfaces, at high Production rates.
* It is not easy to roll internal threads except in few cases.



Tube piercing (or) Roll Piercing:-

* This is a specialized hot working Process for making seamless Thick walled tubes. it utilising two opposing rolls, and hence it is grouped with the rolling Processes.
* This Process is based on when a solid cylindrical Part is compress on its circumference, high tensile stress are developed at its center.
* A mandrel is used to control the size and finish of the hole created by the action.
* compressive stresses on a solid cylindrical billet are applied by two rolls whose axes are oriented at slight angles (about 6°) from the axis of the billet so that their rotation tends to Pull the billet through the rolls.
* If compression is high enough, an internal crack is formed.

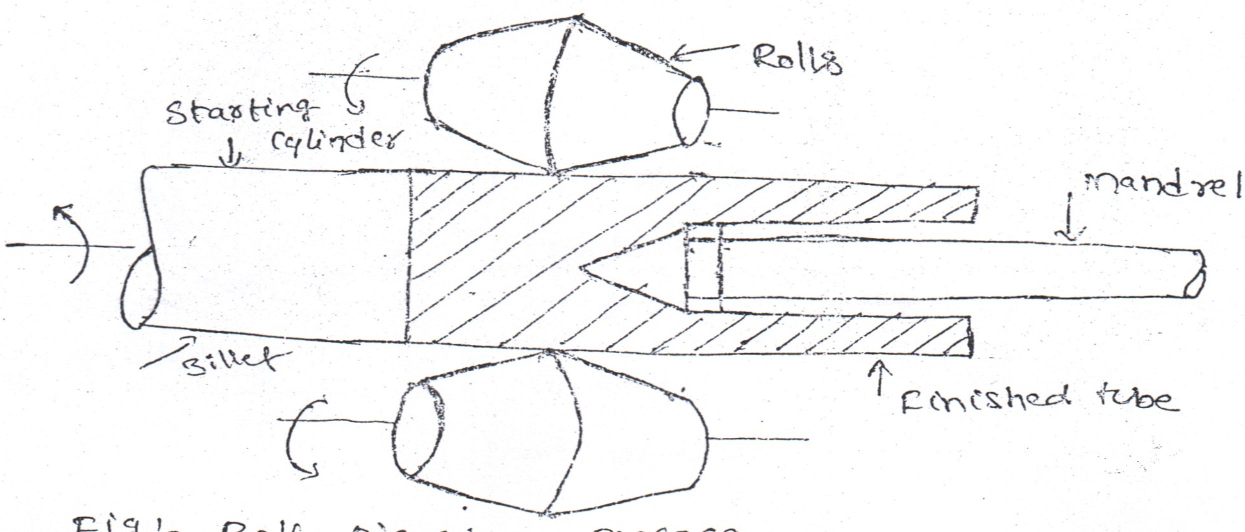


Fig:- Roll piercing process.