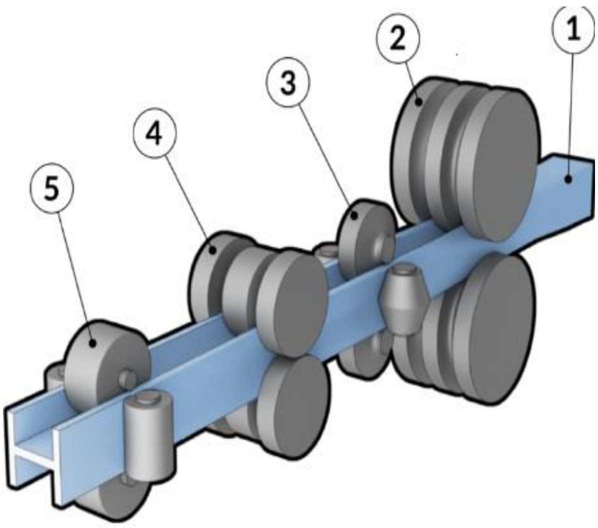
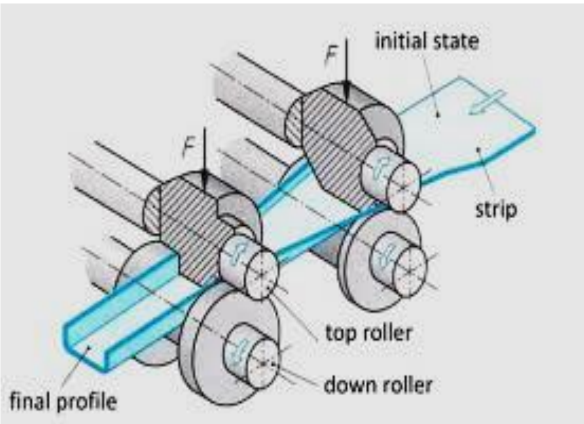
Shape Rolling:

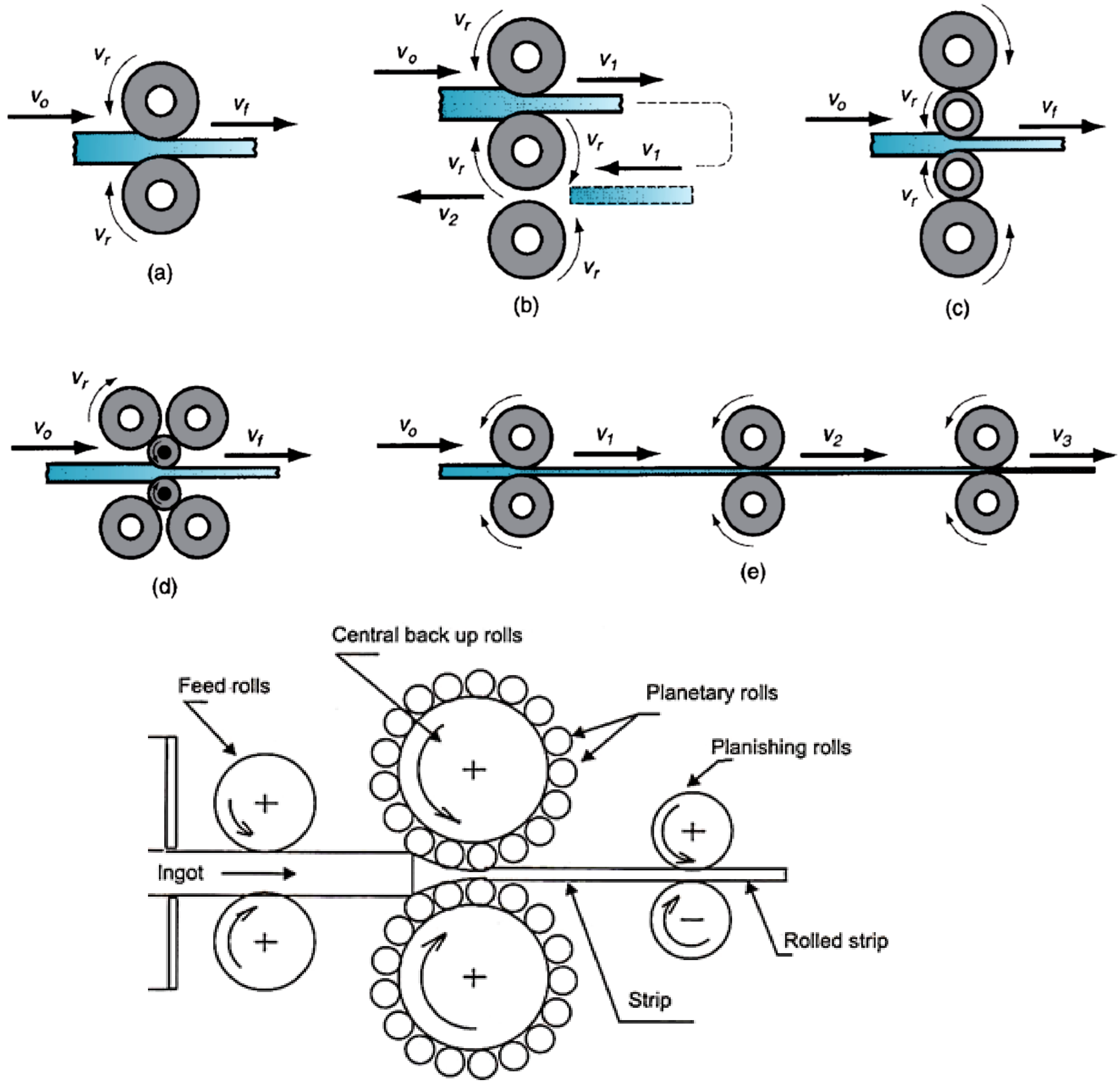
- In shape rolling, the w.p. is deformed into a contoured cross-section, such as I-beam, L-beam, and U-channels; rails for railroad tracks, round and square bars and rods.
- Most of principles that apply in flat rolling are also applicable to shape rolling.
- Shape rolling are more complicated and the w.p. usually starting as a square shape.
- The w.p. in shape rolling requires a gradual transformation through several rolls in order to achieve the final section.
- If a non-uniform deformation is carried out in shape rolling, then some portions of the w.p. are reduced more than others causing a greater elongation for these sections.
- The non-uniform reduction can lead to warping and cracking of the rolled product.





Rolling Mills:

Figure (3-16) explains the rolling mills arrangements.



(f)

Figure (3-16) rolling mills arrangements.

(a) Two-high mill:

- The rolls have diameter (0.6-1.4m).
- The 2-high rolls can be either reversing or non-reversing.
- In non-reversing mill, the rolls always rotate in same direction and w.p. always passes through from the same side.
- The reversing mill allows the direction of roll rotation to be reversed, so that the w.p. can be passed through in either direction.
- The reversing rolling permits a series of reductions to be made through it.
- The disadvantage of reversing rolling is the significant angular momentum (*moment of momentum or rotational momentum*) possessed by large rotating rolls and the associated technical problems included in reversing the direction.

(b) Three-high mill:

- To achieve a series of reductions, the w.p. can be passed through from either side by raising or lowering the strip after each pass.
- The equipment in 3-high mill becomes more complicated because an elevator mechanism is needed to raise and lower w.p.

(c) Four-high mill:

- It uses two smaller-diameter rolls to contact w.p. and two backing rolls behind them.
- The roll-w.p. contact length is reduced by lower radius, this leads to reduce forces, torque and power.
- Owing to high roll forces, these smaller rolls would deflect elastically between their end bearings as w.p. passes through unless the large backing rolls were used to support them.

(d) Cluster rolling mill:

- Another roll configuration that allows smaller working rolls against w.p.

(e) Tandem rolling mill:

- It is used to achieve higher throughput rates in standard products.
- A typical tandem rolling mill may have eight or ten stands, each making a reduction in thickness or a refinement in shape of w.p. passing through.
- With each rolling step, w.p. velocity increases, and problem of synchronizing the roll speeds at each stand is a significant one.
- Modern tandem rolling mills are often supplied directly by continuous casting operations.
- Advantages include elimination of soaking pits, reduction in floor space and shorter manufacturing lead times.

(f) Planetary rolls:

- Each planetary roll gives an almost constant reduction to the w.p. as it sweeps out a circular path between the backing rolls and the w.p.

- The overall reduction is the summation of a series of small reductions by each pair of roll.
- Therefore the planetary mill can hot reduces a **slab** directly to **strip** in one pass.
- The operation requires feed rolls to introduce the slab into the mill.
- Also, it requires a pair of planishing rolls on the exit to improve the surface finish.

Other Deformation Processes Related to Rolling:

Thread Rolling:

- Thread rolling is used to form threads on cylindrical parts.
- It is the most important commercial process for mass producing external threaded components (e.g., bolts and screws).
- Most thread rolling operations are performed by cold working.
- The dies that are used in thread rolling are of two types:
  1- Flat dies which reciprocate relative to each other as shown in figure (3-17).
  2- Round dies which rotate relative to each other as shown n figure (3-18).
- Production rates in thread rolling can be high ranging up to 8 parts/second for small bolts and screws.
- Advantages of thread rolling are: 1- better material utilization, 2- stronger threads due to strain hardening, 3- smoother surface, 4- better fatigue resistance due to compressive stresses introduced by rolling.

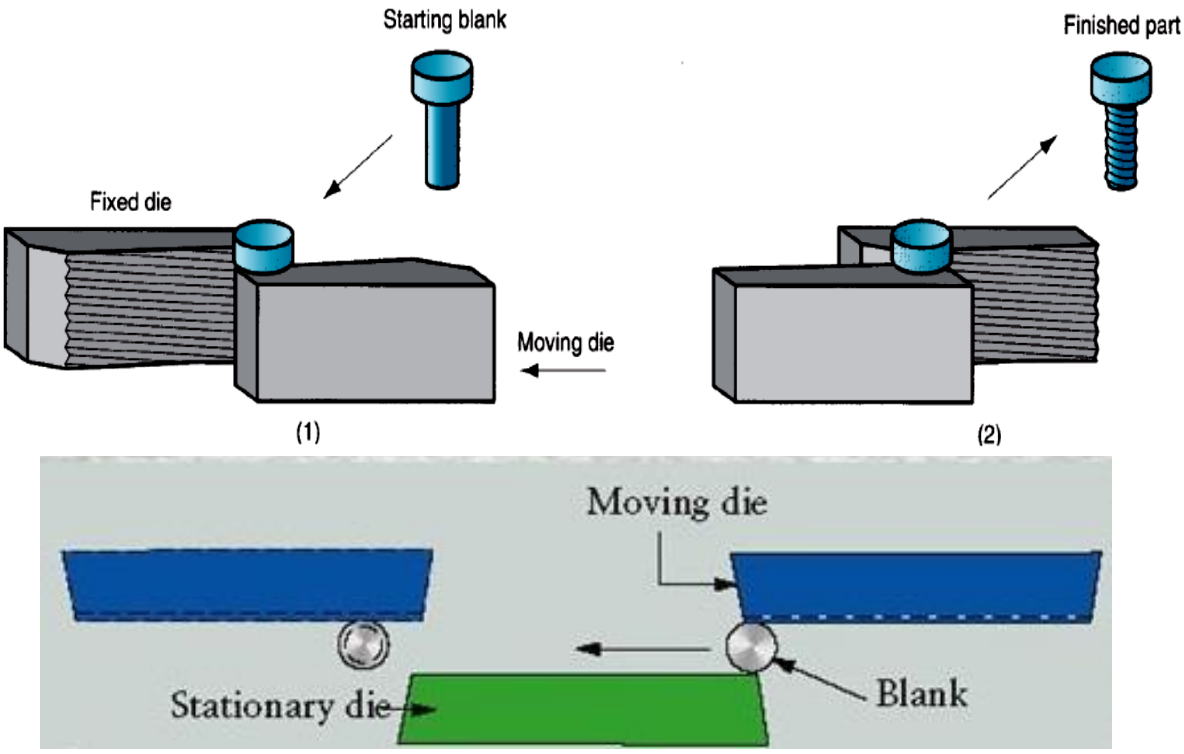


Figure (3-17) Thread Rolling-Flat Dies; (1) start of cycle, (2) end of cycle

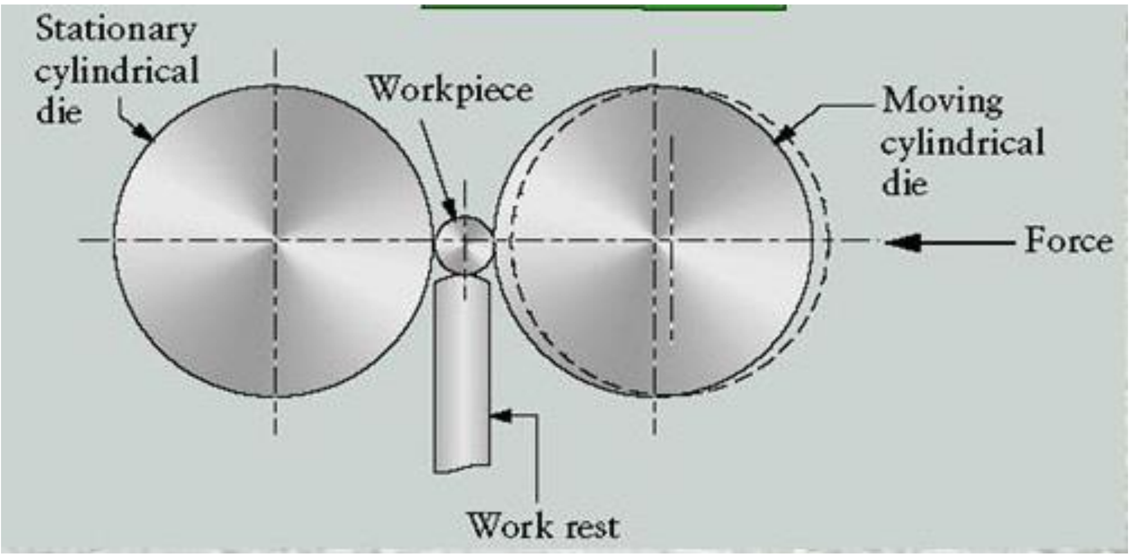
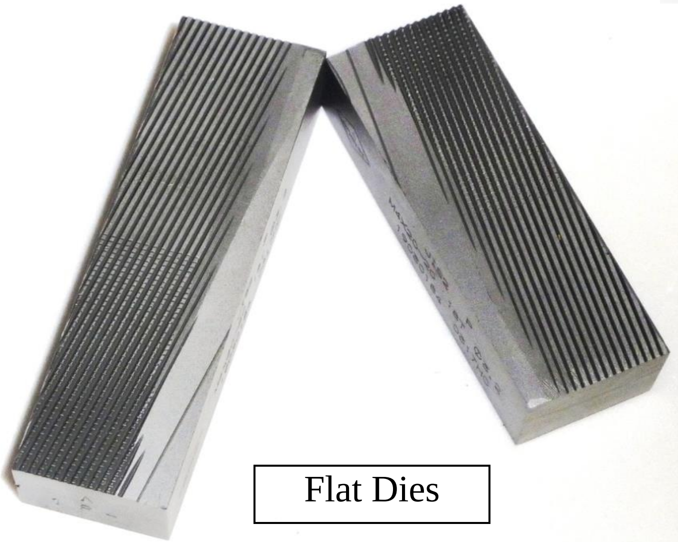
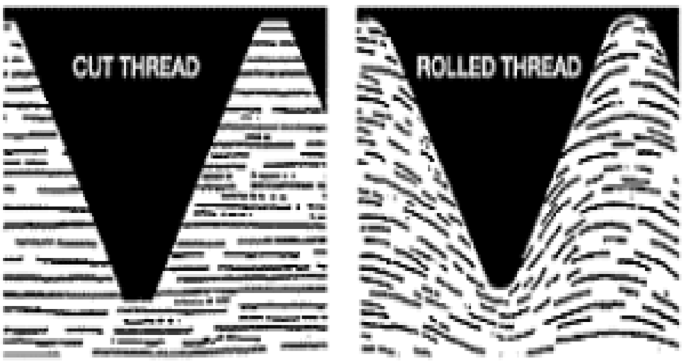


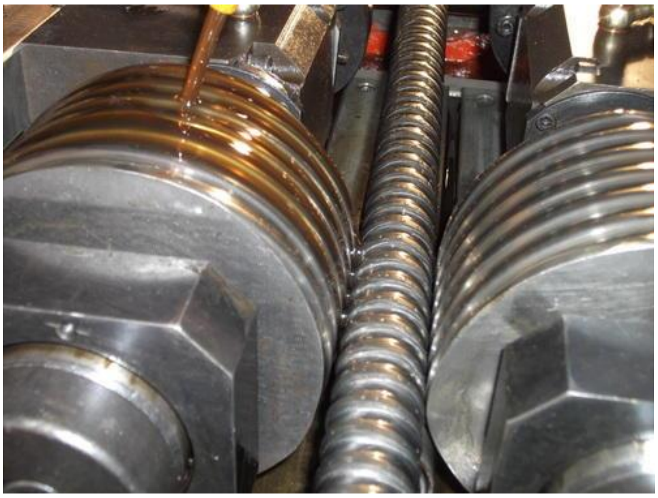
Figure (3-18) Thread Rolling-Round Dies

Bolt vs Screw



Flat Dies





Round Dies

Ring Rolling:

- In this process a thick-walled ring of smaller diameter is rolled into a thin-walled ring of larger diameter as shown in figure (3-19).
- Ring rolling is usually performed as a hot-working process for larger rings and as a cold-working process for smaller rings.
- Applications of ring rolling include: ball and roller bearing races, steel tires for railroad wheels, and rings for pipes, pressure vessel and rotating machinery.
- Advantages of ring rolling are: 1- saving of raw material, 2- ideal grain orientation of the final product, 3- strengthening through cold working.

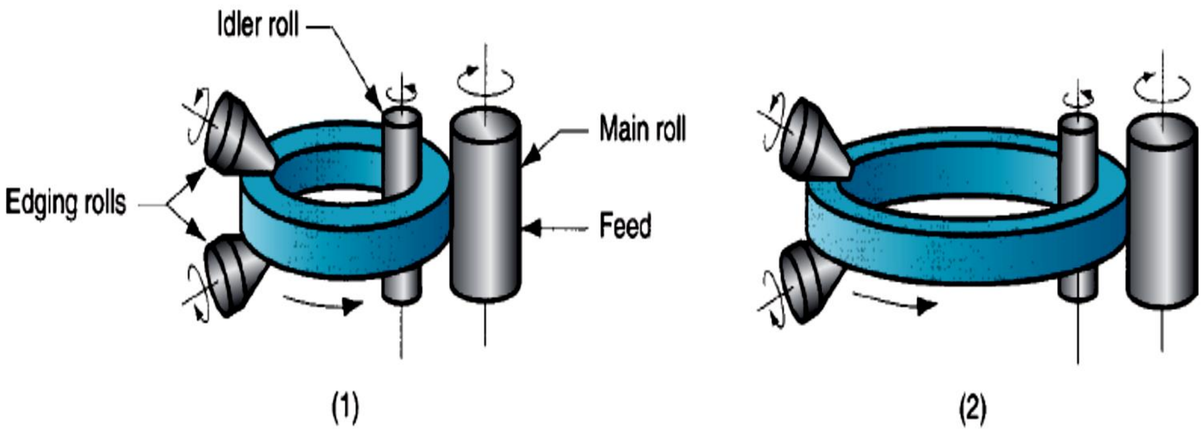
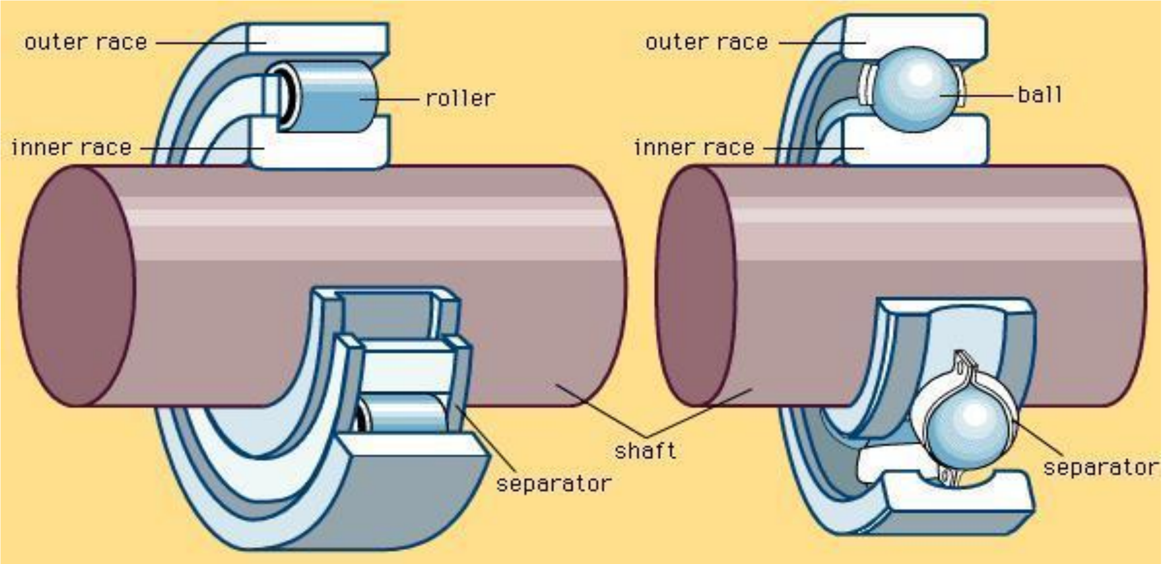
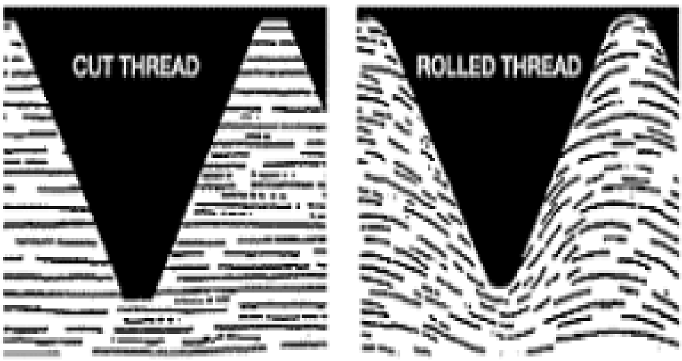


Figure (3-19) ring rolling process; (1) start, (2) completion of process


outer race
roller
inner race
outer race
ball
inner race
shaft
separator
separator

Gear Rolling:

- It is a cold working process to produce certain gears.
- The setup in gear rolling is similar to thread rolling except that the deformed features of the cylindrical blank or disk are oriented parallel to its axis (or at an angle in the case of helical gears) rather than spiraled as in thread rolling.
- Advantages of gear rolling are: 1- higher production rates, 2- better strength and fatigue resistance, 3- less material waste.
- Figure (3-20) illustrates the gear rolling machine.



Grain Flow Lines: unlike machined gears, which cut through the grains of the metal, rolled threads have improved strength due to cold working.

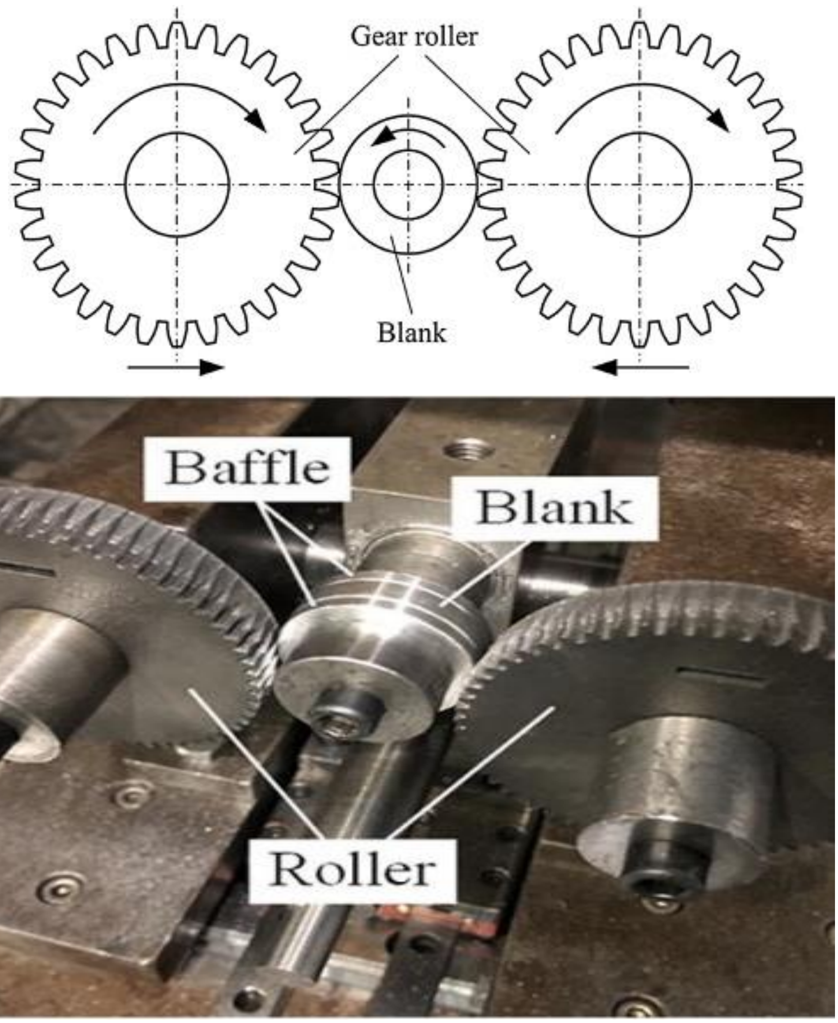
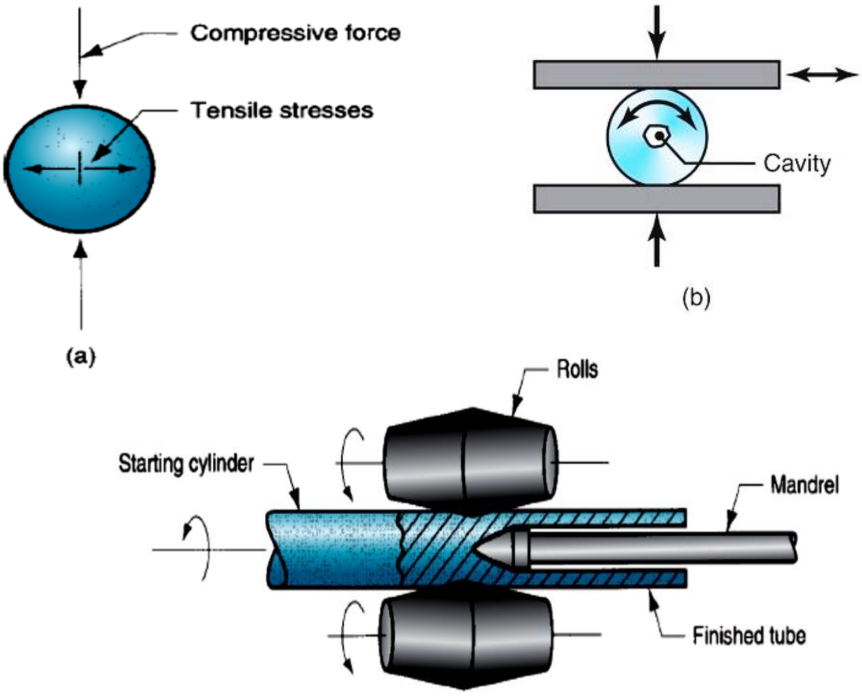


Figure (3-20) Gear Rolling Process

Roll Piercing:

- It is specialized hot working process for making seamless (smooth and without seams or obvious joins) thick-walled tubes. Figure (3-21) explains roll piercing process.
- The process is based on the principle that when a solid cylindrical part is compressed on its circumference, high tensile stresses are developed at its center. If the compression is high enough, an internal crack is formed.
- The two rolls used in this process are utilized to apply the compressive stresses on the solid cylindrical billet.
- The axes of the two rolls are oriented at slight angles (about 6º) from the axis of the billet, so that their rotation trends to pull the billet through the rolls.
- A mandrel is used to control the size and finish of the hole created by the action.



(c)

Figure (3-21) Roll piercing process; (a) formation of internal stresses, (b) formation of cavity at center of the billet, (c) setup of roll mill for producing seamless tubing.

Piercing rolls

Seam pipe

Seamless tube